MINE DELIVERY MODEL: A COMPUTER SIMULATION

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ABSTRACT

The Mine Delivery Model is a Monte Carlo computer simulation of the delivery of mines in detail by ships, submarines, and/or aircraft. Inputs are of such a nature as to permit the simulated execution of any specific mining plan and the outputs provide sufficient information for subsequent evaluation of the plan by a threat assessment model.

The model as programmed for the CDC 1604 Computer consists of five programs. The first two programs convert input data, the third and main program is the mine delivery simulation, the fourth program provides a detailed printout of both inputs and game results, i.e., the calculated parameters for each mine layed accompanied by selected statistics, and the fifth program provides statistics and graphs on the distributions of the mine positions.

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1. Introduction

The Mining Delivery Model is a Monte Carlo computer simulation of sea mine delivery by ships, aircraft, and/or submarines. The purpose of the model is to provide the U. S. Navy the capability of simulating any planned mining operation through the utilization of high speed digital computing equipment. The over-all model concept in mine warfare includes several phases from mine selection through threat assessment, and mine delivery is but one phase of this over-all concept (see figure 1, a schematic showing the several phases and their interrelationships).

In early 1965 the Office of the Assistant to the Chief of Naval Operations for War Gaming Matters (OP-06C) established the requirement for a mine warfare modeling effort and assigned the task to the Computational Analysis Laboratory at the Naval Weapons Laboratory (NWL), Dahlgren, Virginia. In the summer of 1965 the authors of this thesis had the opportunity to view the state of the mine warfare gaming project at NWL. At that time the minefield threat assessment phase of the model was well underway and the mine delivery phase was scheduled to be begun in the spring of 1966. The authors then proposed to undertake the design and building of the mine delivery phase as a thesis project. The topic was of immediate interest to us due to our background experience in the mine forces and because it presented an excellent opportunity to exercise the analysis and gaming techniques studied in the Operations Analysis Curriculum

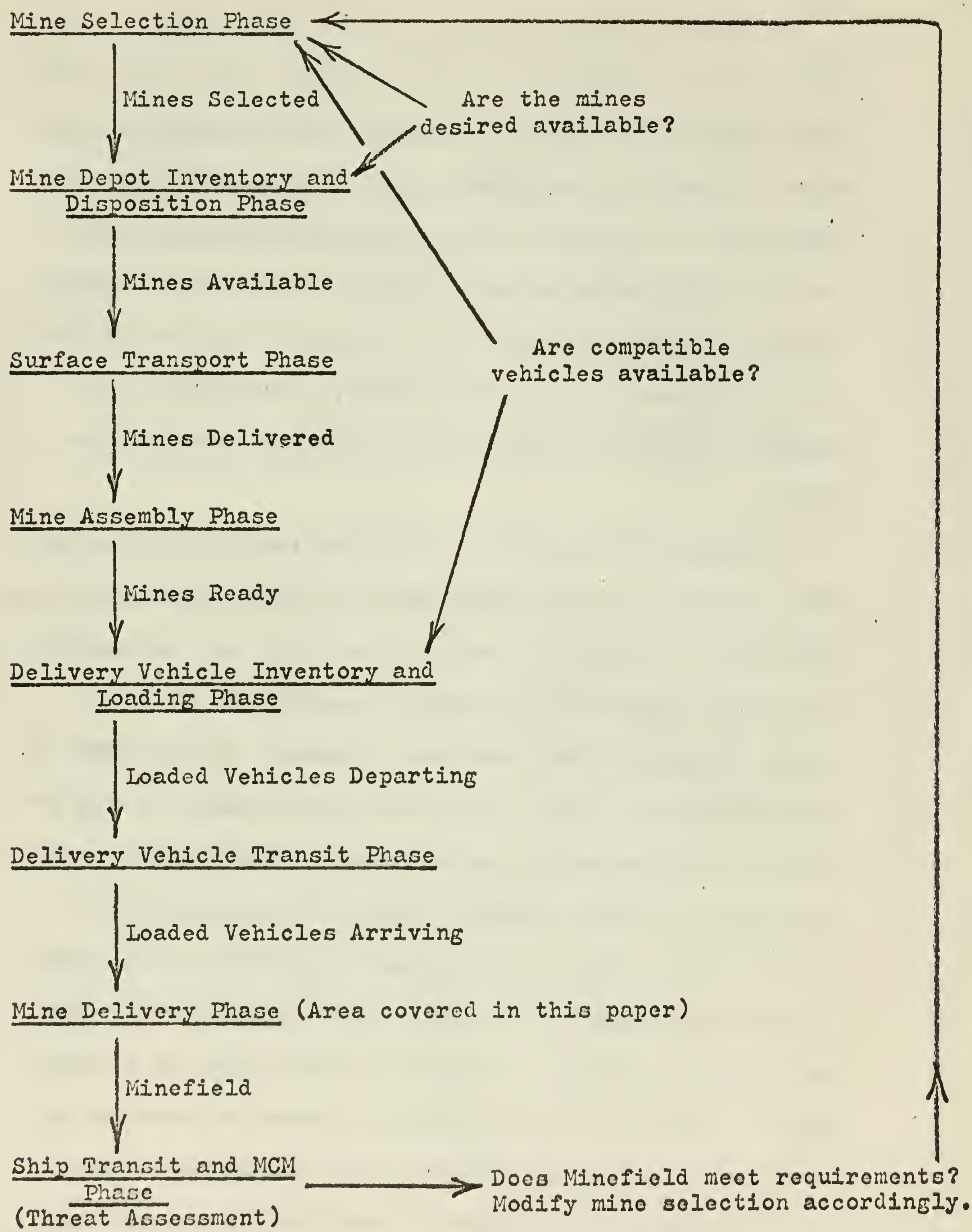


Figure 1. Schematic of the Over-all Model Concept in Mine Warfare

at the U. S. Naval Postgraduate School.

It has been the authors' objective that the mine delivery phase of the over-all model would provide the minefield data necessary for a tie-in operation with the existing threat assessment phase as developed by NWL. Every effort has been made to maintain liason with NWL to ensure compatibility of the model phases. Since several unique approaches to simulation problems have been included, special care has been taken to explain in detail each of these features in subsequent sections and to provide guidelines for the modification of the model where necessary to ensure flexibility and consistency with the requirements of the user.

At the outset it was decided that the model in this thesis would be unclassified, hence all data for the vehicles, mines, and the minefield used in the test runs shown in this thesis were arbitrarily or randomly generated and only represent a cross-section of authentic vehicles, mines and mining plans in the most general way.

The authors wish to take this opportunity to express their gratitude to Professor Alvin Andrus, Operations Analysis Department, U. S. Naval Postgraduate School, for assistance and encouragement as our thesis advisor; Lieutenant Colonel R. V. Schick, U.S.M.C., Office of the Assistant to the Chief of Naval Operations for War Gaming Matters, for his interest and contributions in co-ordinating our efforts with NWL's efforts; and to the personnel of the Amphibious Warfare Section, Naval Weapons Laboratory, and the personnel of the Computer Facility, U. S. Naval Postgraduate School, for their generous cooperation.

2. An Overview of the Mine Delivery Model.

The Mine Delivery Model presented in this thesis simulates the delivery of sea mines by aircraft, ships, and submarines from the time of arrival of the delivery vehicle at the minefield objective area until it completes or aborts its mission, or is attrited, along with the determination of the pertinent mine parameters. The model is programmed in the FORTRAN 63 computer language for the Control Data Corporation 1604 Computer available at the U. S. Naval Postgraduate School; this is a comparable language to the FORTRAN IV language for IBM computers. Special care has been taken to ensure that the coding is also compatible with the IBM 7090/7094 series computers.

The following is a summary of the model's general characteristics.

The geographical limits are a rectangular area of any size which includes the minefield and all geographical points to be used in the simulation.

The offensive forces are limited to a total of 50 delivery vehicles and 167 mines. The vehicles are further limited to a maximum of ten aircraft types, ten ship types, and nine submarine types. Mines are also limited to a maximum of 24 aircraft types, ten ship types, and eight submarine types.

Enemy forces are simulated by appropriate vehicle attrition routines.

All the foregoing limitations may be increased with minor program changes.

The structure of the Mine Delivery Model involves five computer programs linked by data storage on magnetic tape. The five programs are briefly described as follows.

Program GRID is an auxiliary program which transforms minefield geographical data in latitude and longitude to X and Y coordinates in yards relative to a pre-selected reference point. The converted data is stored on magnetic tape for use in program MINDEL. A detailed description of this program appears in Appendix I.

Program SURFIT is an auxiliary program which fits an Nth degree polynomial to a surface. In this particular application it is used to fit polynomials to (1) the minefield bottom contour and (2) the minefield bottom type surface. The coefficients and degrees of the two fitting polynomials are stored on magnetic tape along with the data from program GRID for use in program MINDEL. A detailed description of this program appears in Appendix II.

Program MINDEL is the main program which simulates the delivery operation. It is discussed in detail in the following section. It suffices to summarize here that program MINDEL utilizes the data from magnetic tape and punched card input data to game the events occurring to delivery vehicles and to determine the mine parameters according to the respective mine sequences. A printed summary narrative presents the details of vehicle events and the status of each mine. All input data and the results of each mine lay are stored on magnetic tape for use in program MINDEL1.

Program MINDEL1 is an auxiliary program which provides a detailed printout of all input data and a detailed description of each mine layed and its parameters as determined in program MINDEL. In addition it compiles the statistics of the number of mines layed, buried, not buried, effective, and compromised. The distributions of the mine positions are stored on magnetic tape for use in program LSQRPLOT. A detailed presentation of program MINDEL1 appears in Appendix XI. A discussion of the statistical routines appears in Section Four.

Program LSQRPLOT is an auxiliary program which computes a least squares fit to the cumulative distributions of the mine positions along the minefield X and Y axes, and presents graphs of both frequency and cumulative distributions on the axes. In addition, a random minefield is generated utilizing the statistics compiled in program MINDEL1. This program is discussed in Section Four and a program listing appears in Appendix XII.

The segmenting of the model into five programs was necessitated by the storage capacity of the CDC 1604 Computer available; however, each program is a logical portion of the model for the purposes of parametric analysis and for controlling the degree of information which may be desired by the user. In a typical employment of the model programs GRID and SURFIT would be run once to convert the geographical and bottom data for a specific mining plan. The taped data from these two programs is then available for repeated use by program MINDEL. Program MINDEL is then run for the desired number of iterations and/or for parametric analysis which may be performed by varying the punched card input data. Program MINDEL1, utilizing the taped output of program MINDEL, is then run once for each set of punched card input to program MINDEL. Following each run of program MINDEL1, program LSQRPLOT is run if the extent of the desired information includes the mine position distributions on the two axes.

The approximate storage capacities and running times for the five programs above are:

PROGRAM	STORAGE CAPACITY	RUNNING TIME (Minutes)
GRID	9,000	2.0
SURFIT	12,000	3.5
MINDEL		
a. One iteration	14,000	5.5
b. 80 iterations	14,000	42.0
MINDEL1		
a. One iteration	13,500	3.0
b. 80 iterations	13,500	22.0
LSQRPLOT	24,000	2.5

This data is based on the sample run, a portion of which appears in Appendix XIII.

3. MINDEL: The Mine Delivery Simulation.

This section is a detailed dissertation on Program MINDEL and the background methodology, assumptions, and concepts resulting from the authors' analysis of the mine delivery operation. The real world characteristics of mining vehicles and mines involved in a mining operation have been examined and the critical aspects have been extrapolated to form a usable model as described herein.

In Program MINDEL each vehicle is considered to have arrived at the minefield objective area. The vehicles are selected in order of their arrival and each vehicle is then considered to follow a track attempting to lay its mines in their intended positions. As the vehicle progresses along its track, the attrition and damage routines appropriate to the vehicle type are considered. At each mine release point a sequence of events which is determined by the vehicle and mine characteristics is begun. The outcomes of the events in this sequence determine the final position of the mine and its parameters. With the exception of a few deterministic events, the outcomes of events are probabilistic and each outcome is resolved by comparing a random number from a uniform distribution on the interval zero to one to a probability provided by the user. If the vehicle survives and completes the transit of its assigned track, it is assumed to depart the minefield objective area and the next vehicle is selected. Figure 2 shows the basic logic of the Mine Delivery Model.

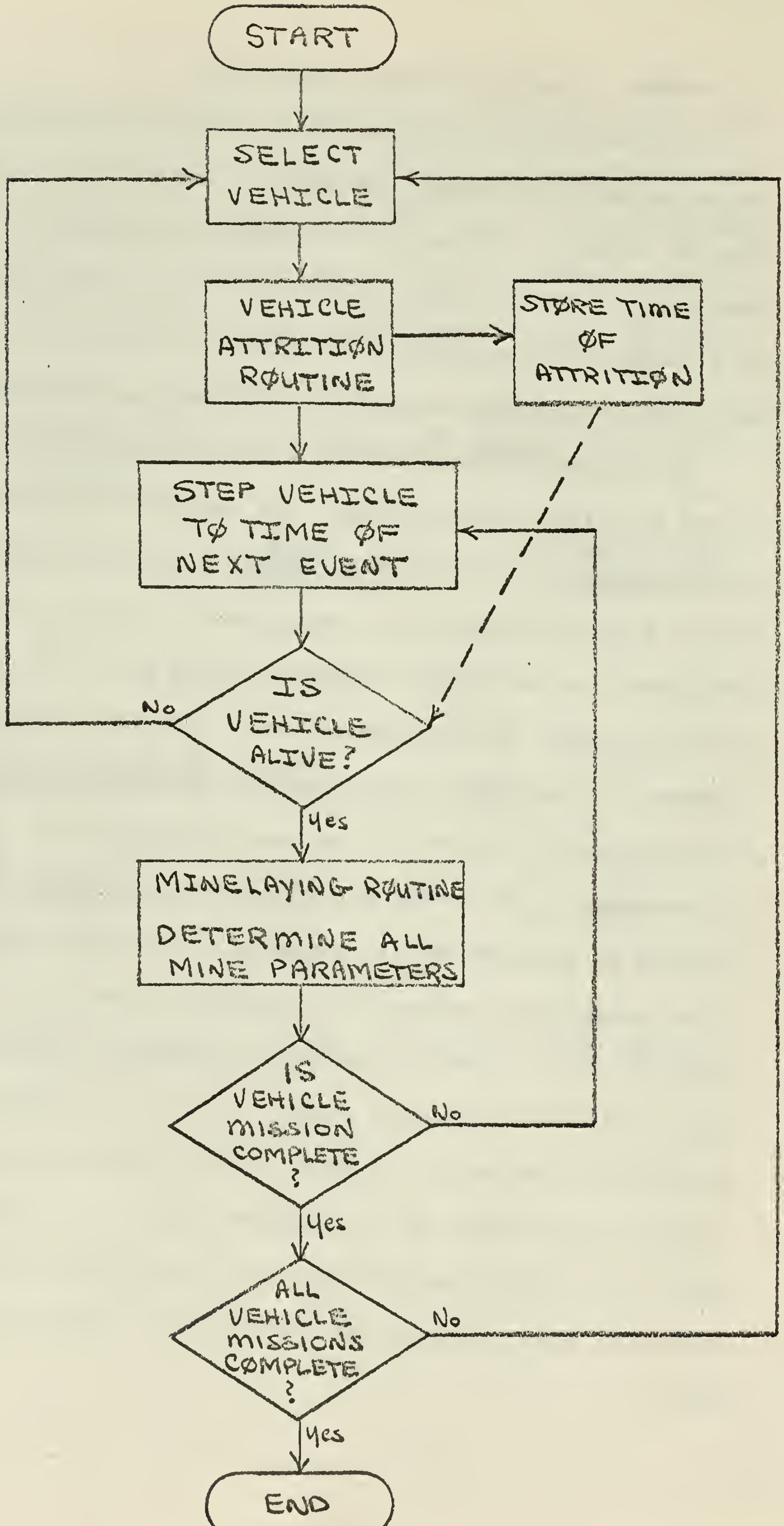


Figure 2. Flowchart of Basic Logic in the Mine Delivery Model.

A more comprehensive commentary of the authors' approach to the mine delivery simulation follows in succeeding paragraphs.

Program MINDEL uses input data from both magnetic tape and punched cards. The taped input includes:

1. Co-ordinates of the minefield perimeter.
2. Co-ordinates of the minefield reference point.
3. Vehicle leg description lists.
4. Parameters of the bottom contour and bottom type polynomials.

The punched card data includes:

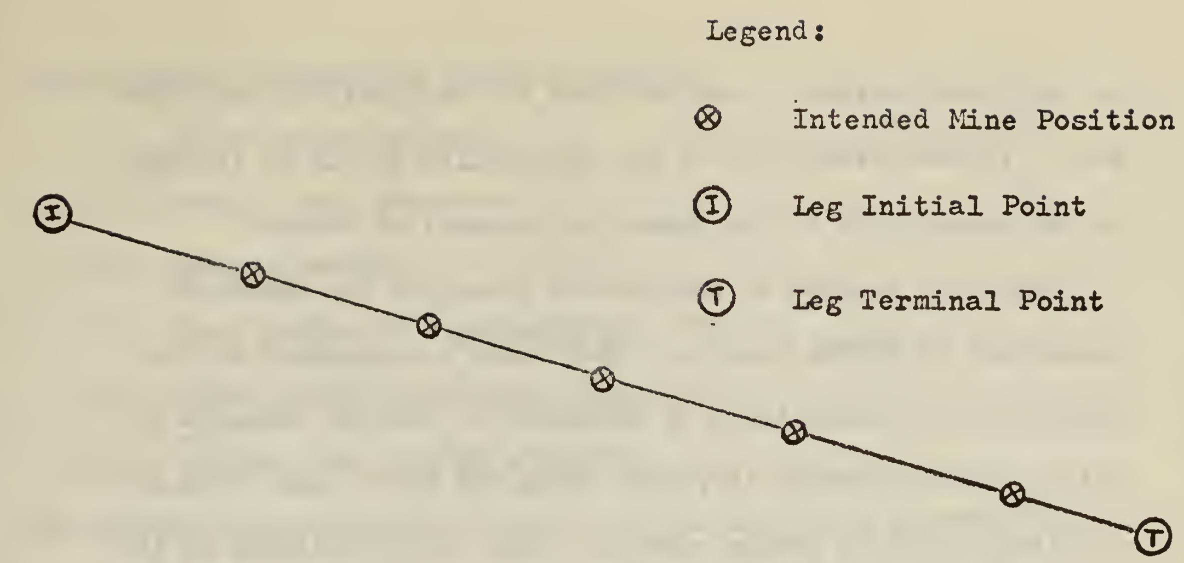
1. Vehicle Arrival List.
2. Vehicle characteristics lists.
3. Mine characteristics lists.
4. Mine Description List.
5. Aircraft Bombrack Array.
6. Submarine end of mission time.
7. Array of initializing values for the pseudo-random number generator.

The above data is read in under indices established by the user. The indices and the array dimensions shown in the sample program listing included in Appendix IV were chosen on the basis of computer storage limitations. If a greater storage capacity is available to the user, a simple change to the appropriate dimension statements, following the guidelines of Appendix IV, will suffice to increase the force limits as desired.

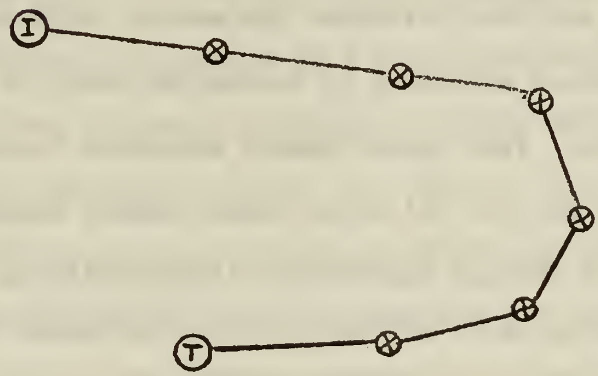
The underlying methodology of the model is based on the concept of the vehicle leg. The leg is a series of points consisting of an initial point, one or more mine intended positions (or mine firing positions in the case of submarine self-propelled mines), and a terminal point. While there are no restrictions on the orientation of a leg or on the orientation of the points on a leg with respect to each other, each pair of points in sequence is considered connected by a straight line segment (see Figure 3). If a vehicle is assigned more than one leg, the legs are considered joined by a straight line from the terminal point of each leg to the initial point of the next leg.

A vehicle, starting from the leg initial point, transits the leg by "passing through" the successive mine intended positions on the leg until it arrives at the leg terminal point. Germane to the concept of "passing through" a mine intended position are the assumptions that a vehicle always attempts to lay each mine at the intended position of that mine, and that at the time of each lay the vehicle considers itself to be at its calculated release point within the limits of its navigational capability.

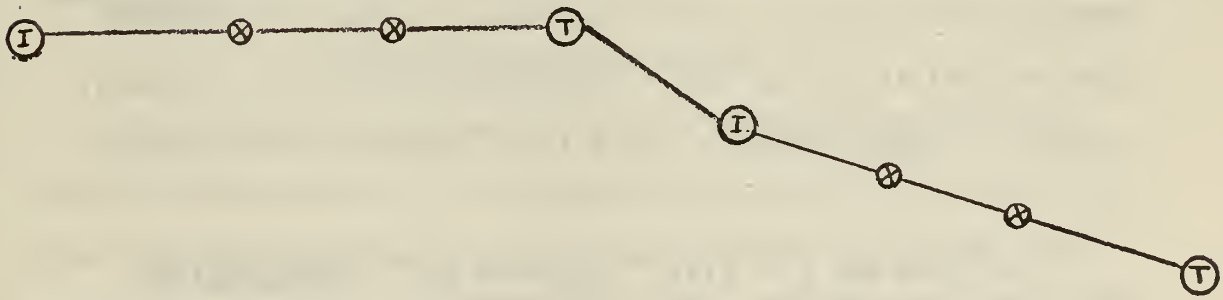
Prior to the beginning of any iterations of MINDEL a submarine end of mission time (TAM) is determined. TAM is the date-time by which submarine operations in the minefield objective area are to terminate. The user has the option of assigning a desired date-time to TAM or assigning it a zero value except when submarines are the only vehicle type used a specific value of TAM must be assigned. When a zero value for TAM is used the submarine(s) must be the first vehicle type(s) to enter the minefield objective area, and TAM is determined within the program to be the time of arrival



Example 1. Single Straight Leg



Example 2. Single Curved Leg



Example 3. Multiple Legs

Figure 3. Graphical Examples of the Leg Concept.

of the first vehicle of another type at the minefield objective area. Further discussion of the application of TAM is included in the description of the Submarine Sequence of Events.

The user assigns an appropriate value for the number of iterations of MINDEL desired. This value is dependent on the sample size the user feels is necessary to provide adequate results. Each iteration is played using the basic input data and a different set of random numbers. This is accomplished by the selection of a new initializing value for the random number generator at the beginning of each iteration. These initializing values may be selected from the set of odd integers from 1 to 67108863 inclusive and they determine the set of uniformly distributed random numbers generated by Subroutine RAN1[1] on the real interval zero to one. This random number generator is utilized throughout the program, and all other random number distributions are obtained from it through appropriate transformations.

In the discussion which follows only one iteration of MINDEL is being described.

Following the duplication of the Aircraft Bombrack Array into a temporary array, necessitated by the destructive features of the bombrack search routine in each iteration, a vehicle is selected from the Vehicle Arrival List. The Vehicle Arrival List contains, in order of their arrival at their first assigned initial points,

[1]M.C. Pike and I.D. Hill, "Algorithm 266," Communications of the ACM, VIII(October, 1965), pp. 605-606.

the following information for each vehicle:

1. Date-time of arrival.
2. Vehicle type indicator.
3. Vehicle number.
4. Total number of legs assigned.
5. Number of bombracks for aircraft.
6. Ordered list of legs assigned.

The vehicle type indicator of the selected vehicle is examined to determine which of the three basic vehicle types it is. If the vehicle type indicator is between 000 and 009 inclusive, the vehicle is a submarine type and is treated as set forth in the Submarine Sequence of Events. If the vehicle type indicator is between 010 and 099 inclusive, the vehicle is a ship type and is treated as set forth in the Ship Sequence of Events. If the vehicle type indicator is between 100 and 999 inclusive, the vehicle is an aircraft type and is treated as set forth in the Aircraft Sequence of Events. Although certain portions of the programing are common to the three vehicle sequences, the vehicle sequences of events which follow are presented separately for purposes of clarity and the common features are pointed out. The three vehicle sequences are described as follows:

Aircraft Sequence of Events

The aircraft type number is found by subtracting 99 from the vehicle type indicator. The aircraft type number then serves as an index for entry into the Aircraft Characteristics List which contains the following information concerning each aircraft type:

of the first vehicle of another type at the minefield objective area. Further discussion of the application of TAM is included in the description of the Submarine Sequence of Events.

The user assigns an appropriate value for the number of iterations of MINDEL desired. This value is dependent on the sample size the user feels is necessary to provide adequate results. Each iteration is played using the basic input data and a different set of random numbers. This is accomplished by the selection of a new initializing value for the random number generator at the beginning of each iteration. These initializing values may be selected from the set of odd integers from 1 to 67108863 inclusive and they determine the set of uniformly distributed random numbers generated by Subroutine RAN1[1] on the real interval zero to one. This random number generator is utilized throughout the program, and all other random number distributions are obtained from it through appropriate transformations.

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Aircraft Sequence of Events

The aircraft type number is found by subtracting 99 from the vehicle type indicator. The aircraft type number then serves as an index for entry into the Aircraft Characteristics List which contains the following information concerning each aircraft type:

1. Aircraft type indicator.
2. Transit speed (knots).
3. Minelaying speed (knots).
4. Minelaying altitude (feet).
5. Probability of mine release.
6. Probability of survival over the objective area.

The minelaying speed is converted to yards per minute and a vehicle type flag is set to control the flow of this sequence in subsequent portions of the program.

The total number of legs and the number of the first leg assigned to the aircraft are extracted from the Vehicle Arrival List. Utilizing the leg number the corresponding leg data is extracted from the Aircraft Leg Description List which contains the following information for each aircraft leg:

1. Leg number.
2. Number of mines to be layed on the leg.
3. X and Y co-ordinates of the leg initial point.
4. For each mine on the leg, the mine number and the X and Y co-ordinates of its intended position.
5. X and Y co-ordinates of the leg terminal point.

The distance between consecutive points on the leg and the time increments to transit those distances at minelaying speed are computed. The time increments are summed and represent an ordered record of the time elapsed (at all points on the leg) relative to the vehicle's time of arrival at its first initial point. If the vehicle is assigned more than one leg, the time increment for the distance between the terminal point and the initial point of the next leg is computed and stored in the ordered record of relative times. All succeeding legs assigned to the vehicle are handled in an identical manner.

Upon completion of the calculation of the record of relative times, it is next determined whether the aircraft is attrited and, if so, at what time? A uniform random number is compared to the aircraft probability of survival for the aircraft type. If the aircraft is attrited, the time of attrition is found by multiplying the aircraft's total time in the minefield objective area by a uniform random number. This time is referred to as "dead time".

With completion of the computation of the foregoing values, the actual simulation of the aircraft mining sequence is begun. The aircraft transits to its first assigned mine release point and the relative time for arrival at this point is compared to dead time. If dead time is the earlier of the two times, the aircraft is attrited and "true dead time" is calculated by adding dead time to the date-time of arrival of the aircraft at its first initial point. The attrition event along with the numbers of the mines remaining on board the aircraft are recorded and the next vehicle is selected. If the aircraft is not attrited at this time, the following sequence of events is initiated:

1. Mine release from aircraft.
2. Parachute deployment.
3. Water impact.
4. Actual position determination.
5. Bottom impact.

6. Burying (bottom mines only).
7. Case and anchor separation (moored mines only).
8. Arming (moored mines only).
9. Cable deployment (moored mines only).
10. Reliability.

The mine release event is begun with a search of the Aircraft Bombrack Array. The array contains a list of the mines, by mine number in order of intended release, as distributed among the six possible bombracks for each aircraft. The number of each mine in a releaseable position is compared with the number of the mine to be layed at this position, as obtained from the Aircraft Leg Description List. If the search is unsuccessful, the mine is considered to be blocked by a prior release failure. If successful, a uniform random number is compared with the probability of release for the aircraft. If the mine does not release or is blocked, this information is recorded and the aircraft proceeds to the next point on the leg. If the mine releases, that mine number is deleted from the bombrack array and the next mine moves into a releaseable position. The information that a mine has been released along with the true time of release is recorded and the aircraft proceeds to the next point on the leg. This sequence of events is repeated until the aircraft is either attrited or arrives at its leg terminal point. If the aircraft has been assigned more than one leg, and it arrives at its next leg initial point without being attrited, the above sequence is repeated for all succeeding legs.

The Aircraft Mine Characteristics List contains the following information:

1. Mine type (II).

2. Probability of parachute deployment.

3. CEP for 3K feet, given that the chute deploys.

4. CEP for 3K feet, given that the chute does not deploy.

5. Probability of water impact damage, given that the chute deploys.

6. Probability of water impact damage, given that the chute does not deploy.

7. Probability of impact damage on the hardest bottom, given that the water depth is less than 20 feet and the chute deploys.

8. Probability of impact damage on the hardest bottom, given that the water depth is less than 20 feet and the chute does not deploy.

9. Probability of burying in the softest bottom.

10. Indicator of moor or bottom type mine.

11. NWL type if bottom mine does not bury/buries.

12. Probability of case/anchor separation.

13. Probability of full anchor cable deployment.

14. Probability that the mine operates, given that it has not been damaged (reliability).

When a mine is released by an aircraft, a uniform random number is compared to the probability of parachute deployment. If the parachute deploys, or the mine is not parachute equipped, the corresponding CEP for an aircraft altitude of 3000 feet, the probability of water impact damage, and the probability of impact damage on the hardest bottom given that the water depth is less than 20 feet are extracted from this list. If the parachute does not deploy, the corresponding probabilities are extracted in place of those mentioned above. In either case, an appropriate modification is made to the probability of burying in the softest bottom when the depth of water at the impact point is found to be less than 20 feet. A uniform random number is then compared to the probability of damage on water impact. If damage occurs, this information is recorded.

The mine's corrected CEP is a function of the appropriate original CEP for an aircraft altitude of 3000 feet and the aircraft's minelaying altitude (see Appendix VI for mathematical background). The corrected CEP is converted to a standard deviation which is used as an input to Subroutine RNORM. This subroutine generates the X and Y errors which are applied to the intended position to get the final position of the mine.

Using the final position of the mine determined above, Subroutine DEPTH is called to find the water depth at that point. If the calculated water depth is negative, the fact that the mine has been layed on the beach is recorded and the vehicle proceeds to the next point on its leg. If the water depth is positive, Subroutine DEPTH is then called again; this time with the necessary arguments for determining the bottom type value at the mine's final position.

The Mine Description List contains the following information about each mine:

1. Mine number.

2. Mine type (II).

3. Mine type (I).

4. Mine case depth (intended).

5. Arming delay.

6. Sterile time.

7. Ship counts.

8. Type of moor.

Depending on whether the mine layed is a moored mine or a bottom mine, as determined from the above list, the sequence of events now splits into two paths. For moored mines, the water depth at the mine's final position is tested. If the water depth is less than 20 feet and the mine's parachute failed to open, the appropriate probability of damage on the hardest bottom is used in conjunction with the calculated bottom type factor to determine the probability of damage on bottom impact. If the mine's parachute did deploy, the same calculations are made using the alternate value of the probability of damage on the hardest bottom. A uniform random number is then compared to the probability of damage on bottom impact. When damage is found to have occurred, this fact is recorded. If the water depth at the mine's final position is found to be greater than 20 feet, the probability of damage on bottom impact is considered to be negligible.

To determine whether case and anchor separate, a uniform random number is compared to the probability of case/anchor separation. If separation does not occur this event is recorded and if the mine requires case/anchor separation in order to arm, the failure to arm is also recorded (the fact that the mine does or does not require case/anchor separation in order to arm is determined from the indicator of moor or bottom type in the Aircraft Mine Characteristics List). For moored mines not requiring case/anchor separation to arm, reliability is tested as below. The mine is then considered to come to rest on the bottom at its final position and the aircraft proceeds to its next point. If the case and anchor separation takes place, the case depth is then determined by comparing a uniform random number to the probability of full cable deployment. If the mooring cable fails to deploy fully, the intended full cable deployment length is multiplied by a uniform random number; otherwise the cable deploys fully in accordance with its case depth setting. In both cases the final case depth is calculated by two techniques, one for fixed case depth moored mines and another for fixed cable length moored mines; both of which utilize intended case depth and water depth at the mine's final position. Finally, given that the mine has not been damaged, it is determined and recorded whether the mine operates or not by comparing a uniform random number and the mine's reliability.

For bottom mines, the initial steps involving the determination of the probability of damage on the bottom are the same as for moored mines. In addition, the probability of burying, as a function of the probability of burying in the softest bottom and bottom type, is determined. This probability is modified by the addition of a factor of .1 if the water depth is less than 20 feet and the mine's parachute deployed or by the addition of a factor of .2 if the water depth is less than 20 feet and the mine's parachute did not deploy. It is determined if the bottom mine is a type for which burying is desirable or not desirable (by checking the indicator of moor or bottom type for the mine in the Aircraft Mine Characteristics List) and a uniform random number is then compared to the probability of burying. If the mine is designed to bury and it does not or if it is designed not to bury and it does, a reduced actuation sensitivity (NWL type if bottom mine does not bury/buries in the Aircraft Mine Characteristics List) is selected and the event is recorded. Finally, if the mine has not been damaged, a uniform random number is compared to the mine reliability and the outcome is recorded.

Following the laying of a bottom or moored mine the events as recorded are written on magnetic tape and the aircraft proceeds to its next point.

It should be noted at this point that both "damaged" and "unreliable" here carry a special connotation. "Damaged" implies that the mine has been rendered inoperable. "Unreliable" implies that although the mine is not damaged in the laying sequence, it fails, totally, to operate.

Ship Sequence of Events

The ship type number is found by subtracting nine from the vehicle type indicator. The ship type number then serves as an index for entry into the Ship Characteristics List which contains the following information for each ship type:

1. Ship type indicator.

2. Transit speed (knots).

3. Minelaying speed (knots).

4. Navigational error (yards).
   a. Least.
   b. Average.
   c. Greatest.

5. Probability of mine release.

6. Maximum time delay.

7. Probability of some damage to the ship type for the first half-hour in the minelaying objective area.

The minelaying speed is converted to yards per minute and a vehicle type flag is set to control the flow of this sequence in subsequent portions of the program. Additionally, the navigational error values are extracted from the Ships Characteristics List and a flag indicating that no ship damage has occurred is set.

Ship leg information and the record of relative times is determined from the Ship Leg Description List, which is identical in format to the Aircraft Leg Description List. Upon completion of the foregoing and utilizing the probability of some damage for the first half-hour in the minelaying objective area and the total time in the minefield, the probability of some damage occurring is determined and tested as shown in Appendix VIII. If damage does not occur, the time of damage is set to a value greater than the ship's total time in the field. If the ship does suffer some damage, the time of damage is determined by multiplying the ship's total time in the field by a uniform random number. This time is again referred to as "dead time".

The actual simulation of the ship mining sequence is now begun. The ship transits to its first mine release point and the probability of release is compared to a uniform random number to determine if the mine releases on the first attempt. Ship layed mines are considered to always release due to the simplicity of ship mine racks and the availability of alternative means of launching the mine. However, if the mine does not release on the first attempt, a time delay is computed by multiplying the maximum time delay by a uniform random number. The X and Y distances traveled during this delay time are calculated for use in the navigational error routine and the time delay is added to the intended time of release. The computed release time is then compared to "dead time". If "dead time" is the earlier of the two times, the ship is considered to have suffered some damage at "dead time", and the event is recorded. The type of damage is randomly determined from among the following:

1. Speed reduced by one-half.
2. Navigational error doubled.
3. Sunk.
4. Aborts mission.
5. No effect on mission.

The applications of the type of damage are discussed in Appendix VIII, and only consider damage in the ways it may affect the minelaying mission. Following the determination of the type of damage, appropriate ship parameters are adjusted or the mission is terminated. When a ship minelaying mission is terminated, this event and the mines remaining on board the ship are recorded and the next vehicle is selected.

If the mission continues, the damage flag is set so no further tests for damage will be made and when "dead time" is later than the computed release time the mine is released at the computed release time.

When a mine is released the following sequence of events is initiated:

1. Actual position determination.
2. Bottom impact.
3. Burying (bottom mines only).
4. Case and anchor separation (moored mines only).
5. Arming (moored mines only).
6. Cable deployment (moored mines only).
7. Reliability.

The basic logic for determining the outcomes of these events is essentially the same as that described in the Aircraft Sequence of Events. The only significant exception being the navigational error routine, which is described in Appendix VII. The various probabilities and indicators in this instance are taken from the Ship Mine Characteristics List which contains the following information for each ship layed mine type:

1. Mine type (II).
2. Probability of damage on the hardest bottom, given that the depth is less than 20 feet.
3. Probability of burying in the softest bottom.
4. Indicator of moor or bottom type.

5. NWL type if bottom mine buries/does not bury.

6. Probability of case/anchor separation.

7. Probability of full anchor cable deployment.

8. Reliability.

The ship continues to transit each of its assigned legs until it arrives at the terminal point of its last leg or is sunk or aborts the mission. All the events are recorded and the outcomes of the laying events are written on magnetic tape.

Submarine Sequence of Events

The submarine type number is set equal to the vehicle type indicator. The submarine type number then serves as an index for entry into the Submarine Characteristics List which contains the following information concerning each submarine type:

1. Submarine type indicator.

2. Transit speed (knots).

3. Minelaying speed (knots).

4. Navigational error (yards).
   a. Least
   b. Average
   c. Greatest

5. Probability that the mine is ready at firing time (PMR).

6. Maximum firing time delay (FTDM) (minutes).

7. Probability of detection (PD).

8. Probability that the submarine has knowledge of a detection, given that a detection has occurred (PKD/D).

9. Probability that the submarine thinks detection has occurred, given no detection (PKD/ND).

10. Probability that the submarine suspends operations, given it has knowledge of detection (PSO/KD).

11. Probability that the submarine will return, given it has suspended operations (PR/SO).

12. Probability that the submarine will return, given an unsuccessful attack (PR/UA).

13. Probability of attack, given a detection (PA/D).

14. Probability of a successful attack, given an attack (PSA/A).

15. Distance from the minefield perimeter to the one-hundred fathom curve (D(100)).

The minelaying speed is converted to yards per minute and a vehicle type flag is set to control the flow of this sequence in subsequent portions of the program. Additionally, the time required for the submarine to reach the 100 fathom curve from the minefield using transit speed is calculated and the navigational error values are extracted.

Submarine leg information and the record of relative times is determined from the Submarine Leg Description List in basically the same manner as was described for aircraft. The Submarine Leg Description List contains the following information for each submarine leg:

1. Leg number.
2. Number of mines to be layed on the leg.
3. X and Y co-ordinates of the leg initial point.
4. For each mine on the leg, the mine number, the X and Y co-ordinates of the submarine's firing position, and the X and Y co-ordinates of the mine's intended position.
5. X and Y co-ordinates of the leg terminal point.

The additional information provided by the X and Y co-ordinates of the submarine firing position is necessitated by the submarine's capability to lay self-propelled mines.

It is obvious upon examination of the submarine mining operation that the submarine "detection/attrition" routine can not be as simply modeled as that of aircraft and ships. The submarine's best defense is evasion and the fact that it conducts the mining operation covertly dictates complex techniques for simulating the numerous possible combinations of detection, attack, and evasive tactics. The several probabilities concerning detection, attack, and tactics are extracted from the Submarine Characteristics List and are combined to form a set of exhaustive and mutually exclusive events as described in Appendix IX. One of the most important tactics provided for is that the submarine can leave the field and return at a later time, but it is subject to detection and attack after each subsequent return. Following the combining of the several probabilities above, "dead time" is calculated by multiplying the submarine's expected time in the minelaying objective area by a uniform random number. In this instance "dead time" is the occurrence of one of the possible detection/attrition events.

The actual simulation of the submarine mining sequence is begun with the submarine transiting to its first firing position. The probability that the mine is ready is compared to a uniform random number. If the mine is not ready to fire, a time delay in tenths of a minute is found by generating a uniform random number. The delay is then compared to the maximum allowable time delay

(FTDM). If the time delay is less than the maximum allowable time delay, it is added to the original firing time. This new firing time is then compared to the original firing time of the next mine. If the new firing time is the earlier of the two times, the test to determine if the mine is ready is made again. The cycle is repeated until the mine is determined to be ready to fire, or the maximum allowable time delay is exceeded, or the firing time of the next mine is approached. In the latter two cases the mine is not layed, the information is recorded, and the submarine proceeds to its next firing point. This cycle of events is included to simulate the submarine's unique capability to maneuver as necessary to maintain firing position when a delay occurs. However, when the firing delay becomes excessive, the submarine will elect to leave a gap in the field due to the complexities of rearranging its firing sequence plan and mine storage.

When a mine is found ready to be fired, the original (or revised) firing time is compared to "dead time". If "dead time" is the earlier of the two times, the type of detection/attrition event is randomly determined as described in Appendix IX. Although there are fourteen possible detection/attrition events, each of which is handled differently, they can be summarized by stating that the submarine takes no action, is attrited or aborts the mission, or leaves the field and returns at some later time. If the submarine is attrited or aborts the mission, the event and the mines remaining on board are recorded, and the next vehicle is selected. When the submarine elects to leave the field, the time out of the field is determined by the cause of the submarine leaving the field and is primarily a function of the transit time to the 100 fathom curve. Having left the field the submarine can only return if its time of return does not exceed the submarine end of mission time (TAM). Upon return the submarine resumes minelaying operations at the point of suspending operations and a new "dead time" is computed. When the submarine takes no action, or the original (or revised) firing time is earlier than "dead time", the firing time is compared to TAM and the submarine either terminates operations or the mine is fired.

When a submarine mine is fired, the following sequence of events is initiated:

1. Determination of failure for self-propelled mines.
2. Actual position determination.
3. Bottom impact.
4. Burying (bottom mines only).
5. Case and anchor separation (moored mines only).
6. Arming (moored mines only).
7. Cable deployment (moored mines only).
8. Reliability.

The basic logic for determining the outcomes of the above events is essentially the same as that described in the Aircraft Sequence of Events. The two significant exceptions are the navigational error routine, which is the same as that for ships (see Appendix VII), and the self-propelled mine position and failure routine, which is described in Appendix X. The various probabilities and indicators in this instance are taken from the Submarine Mine Characteristics List which contains the following information for each submarine layed mine type:

1. Mine type (II).
2. Probability of damage on the hardest bottom.
3. Probability of burying in the softest bottom.
4. Indicator of moor or bottom type.
5. NWL type if bottom mine buries/does not bury.
6. Probability of case/anchor separation.
7. Probability of full anchor cable deployment.
8. Probability of a normal run for a submarine self-propelled mine.
9. Probability of a motor failure, given a failure for a self-propelled mine.
10. Probability of a gyro failure, given a failure for a self-propelled mine.
11. Probability of a depth failure, given a failure for a self-propelled mine.
12. CEP for a normal run of a self-propelled mine.
13. Reliability.

The submarine continues to transit each of its assigned legs until it arrives at the terminal point of its last leg or otherwise terminates the mission. All events are recorded and the outcomes of the laying events are written on magnetic tape.

The foregoing is an attempt to provide a description of the general logic flow in the mine delivery simulation. It should be evident that numerous devices not mentioned here, such as indices and flags, have been used to direct the logic flow. The application of these devices is apparent from the program listing, list of variable names, and flow charts which appear in Appendices IV and V.

4. Applications of the Mine Delivery Model.

Now that the Mine Delivery Model has been described, what are its uses? In brief, the model's purpose is to examine and simulate in detail the effects of the delivery vehicles characteristics, individual mine characteristics, and bottom characteristics on the final minefield. The general technique in use today in the modeling community is the generation of a planned minefield by some selected probability distribution with the normal and uniform distributions being most popular for the purposes of threat assessment. It is the authors' contention that this approach does not adequately reflect the effects of vehicle characteristics, such as maneuverability and navigational error, on the final minefield pattern regardless of the randomness intended. Also, it ignores the effects of bottom characteristics. If it is not already apparent from the description of the simulation that there are several factors regarding each mine which will influence the effectiveness of the resultant minefield, it is hoped that the reader will be convinced of this fact as well as the limitations of assuming some distributions on the axes when he has finished reading this section.

There are three general categories of information available from the use of the Mine Delivery Model. The first is the Summary Narrative (MINDEL) which presents information pertaining to the delivery vehicles. In addition to the record of events occurring to each vehicle, this narrative indicates the mines layed or not layed, and why, by mine number. This information is of limited applicability. Since vehicle attrition is directly related to the inputs provided by the user, vehicle attrition is of value only with respect to its effect on which particular mines are layed and the total number of mines layed. Additionally, although no vehicle interaction is programed into the model, the chronological record of events provides the user with a limited capability for investigating such interaction.

The second category of information is the Detailed Narrative (MINDEL1) which presents the results of the laying sequence for each mine layed plus the following five statistics for each iteration:

1. Number of mines layed.
2. Number of mines effective.
3. Number of mines buried.
4. Number of mines not buried.
5. Number of mines compromised.

The number of mines layed per iteration directly reflects the success of the delivery operation. This coupled with the number of effective mines and the number of mines buried or not buried determines the effectiveness of the minefield. Although the mines layed and not effective are not known to be considered in existing threat assessment models, the parameters of such mines are included in the Detailed Narrative in anticipation of the introduction of minehunting features into threat assessment models. The number of mines compromised is considered of interest to the minefield planner because of the loss of the element of surprise for covert fields, and because of the fact that the enemy's countermeasures effectiveness is greatly enhanced by the recovery of even a single mine.

The third and last category of information is the distributions of mine positions (LSQRPLOT). The program LSQRPLOT is included in this paper as one possible course of action utilizing the frequency and the cumulative distributions generated. Samples of the graphical output of program LSQRPLOT appear in Figures 8, 9, 10, 11, 12 and 13, and the program listing appears in Appendix XII.

As pointed out in the opening paragraph of this section, the procedure for generating mine positions for threat assessment models today involves the use of one of a few standard probability distributions. It has been our purpose to demonstrate that the final result of a mine delivery operation is not a purely random field, but bears the signatures of the vehicles which layed the field. Figure 4 shows the intended positions of the 167 mines which could be representative of a planned minefield. Figures 5, 6, and 7 represent the possible results of the execution of this mining plan. It should be apparent that:

1. Vehicle navigational error plays an important role in the final minefield distribution. The distortion to the intended patterns introduced by the aircraft layed mines, based on the input data, is most evident in the eastern portion of the sample minefields.
2. The effect of vehicle attrition on the intended minefield pattern is a function of the time of attrition and the

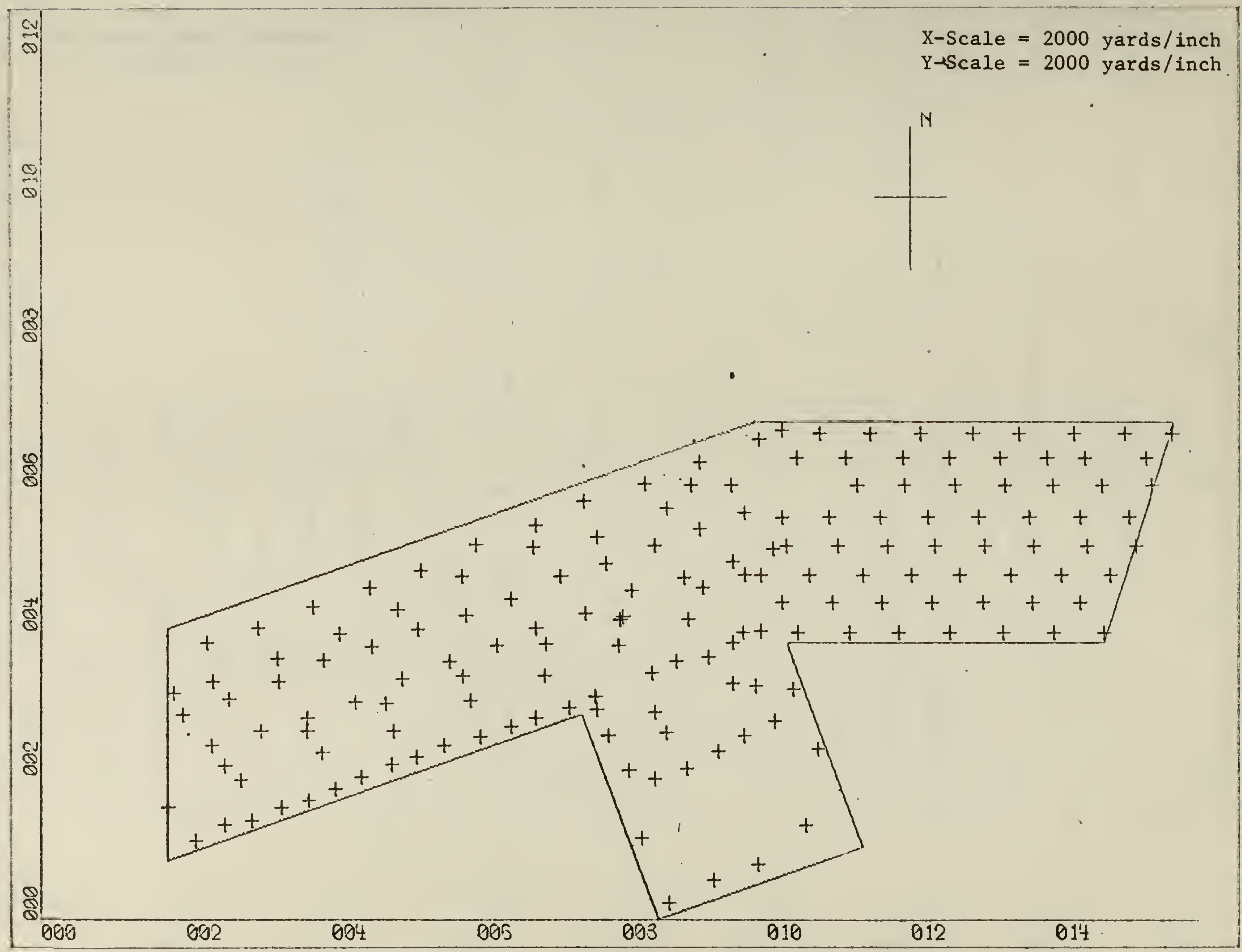

Figure 4. Intended Mine Positions.

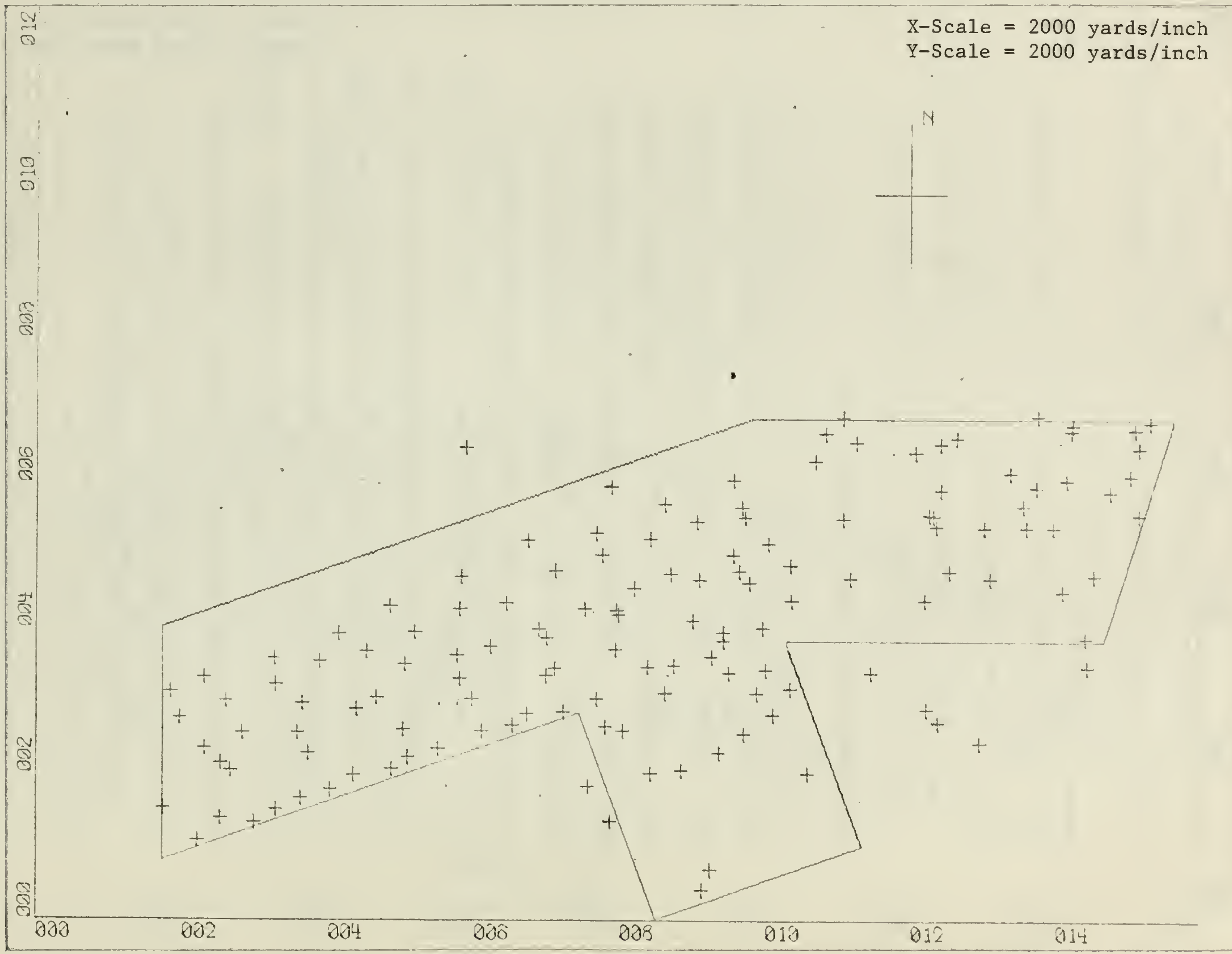

Figure 5. Sample Run - Final Mine Positions Generated by MINDEL.

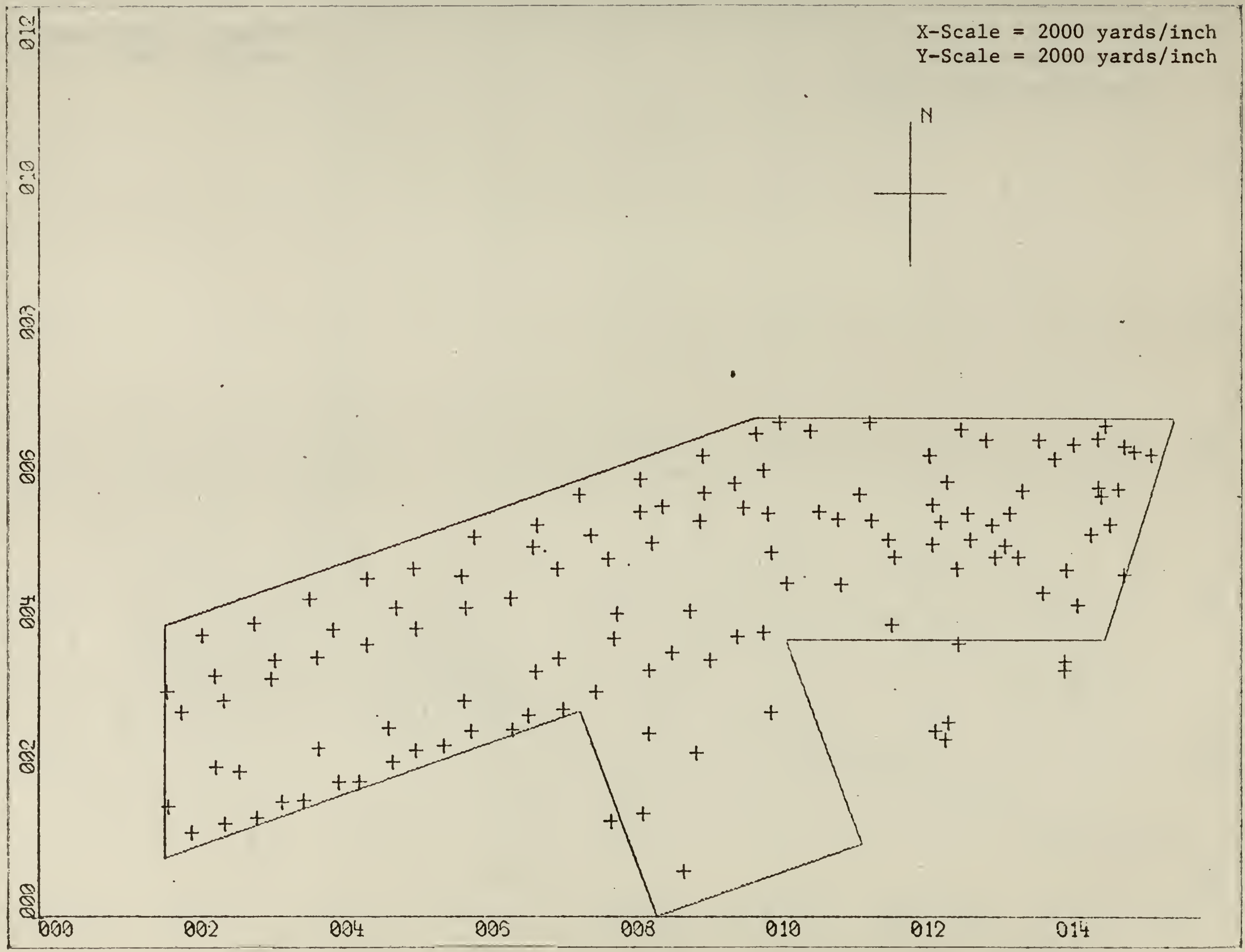

Figure 6. Sample Run - Final Mine Positions Generated by MINDEL.

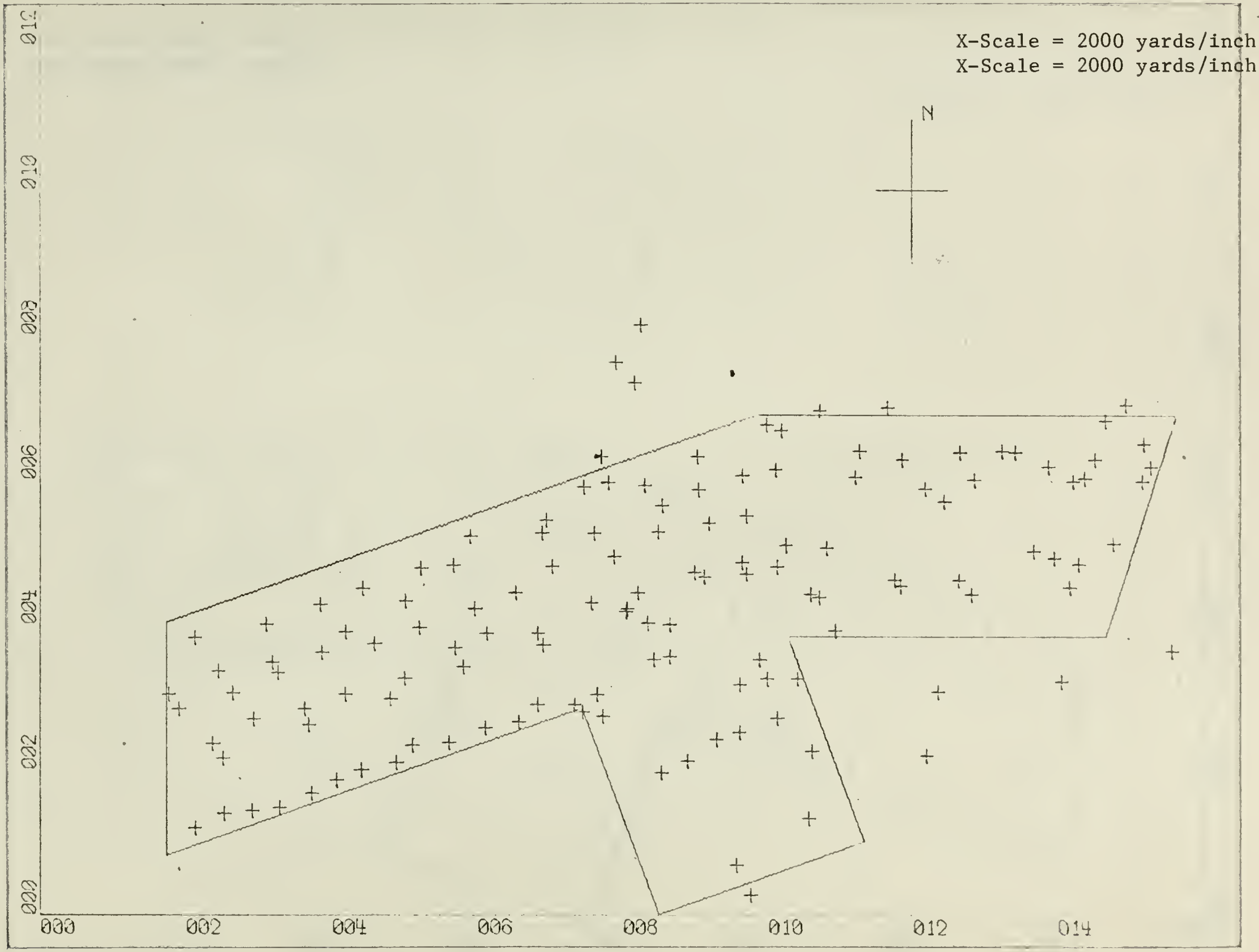

Figure 7. Sample Run - Final Mine Positions Generated by MINDEL.

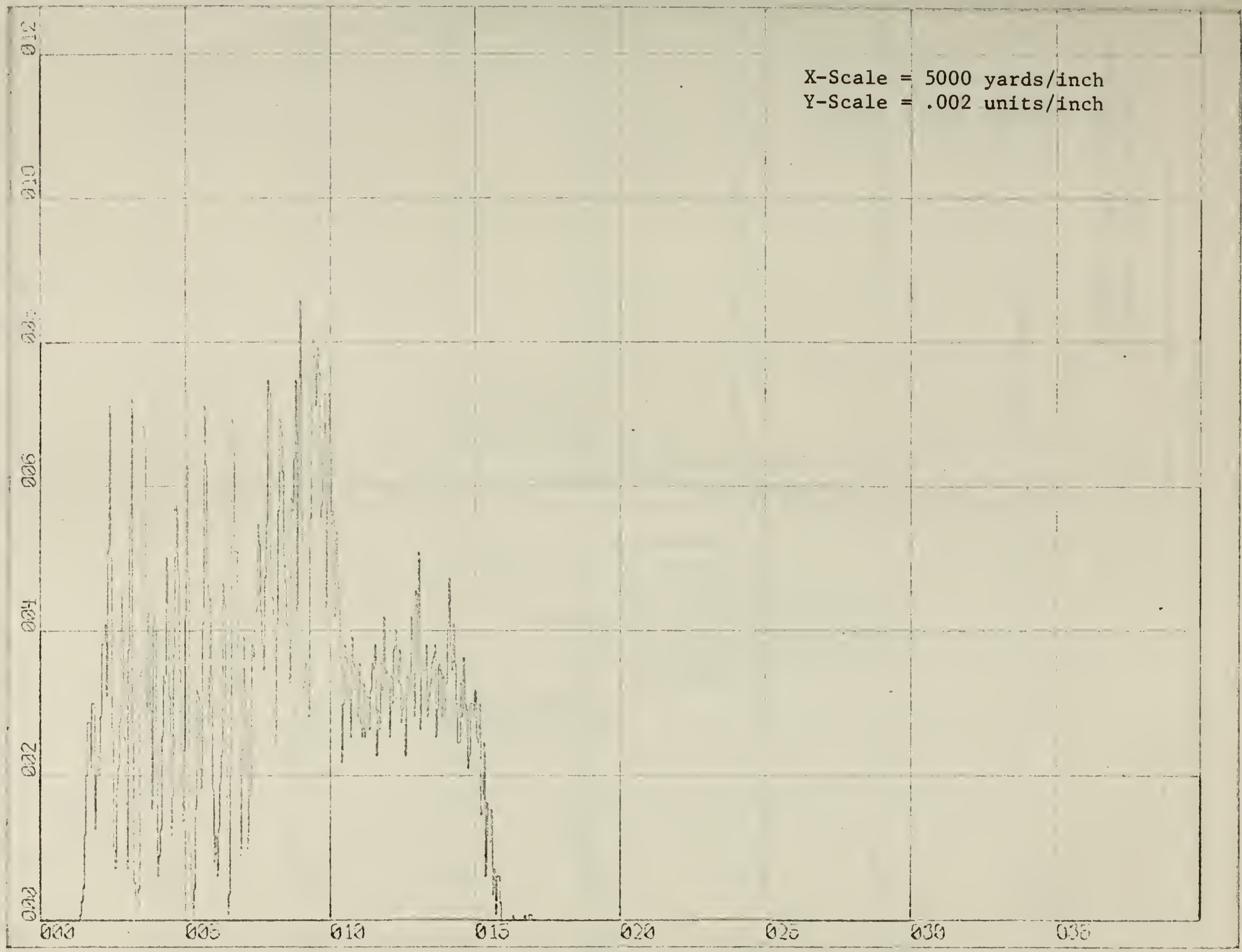

Figure 8. Mine Frequency Distribution on the X-Axis for all Sample Runs.

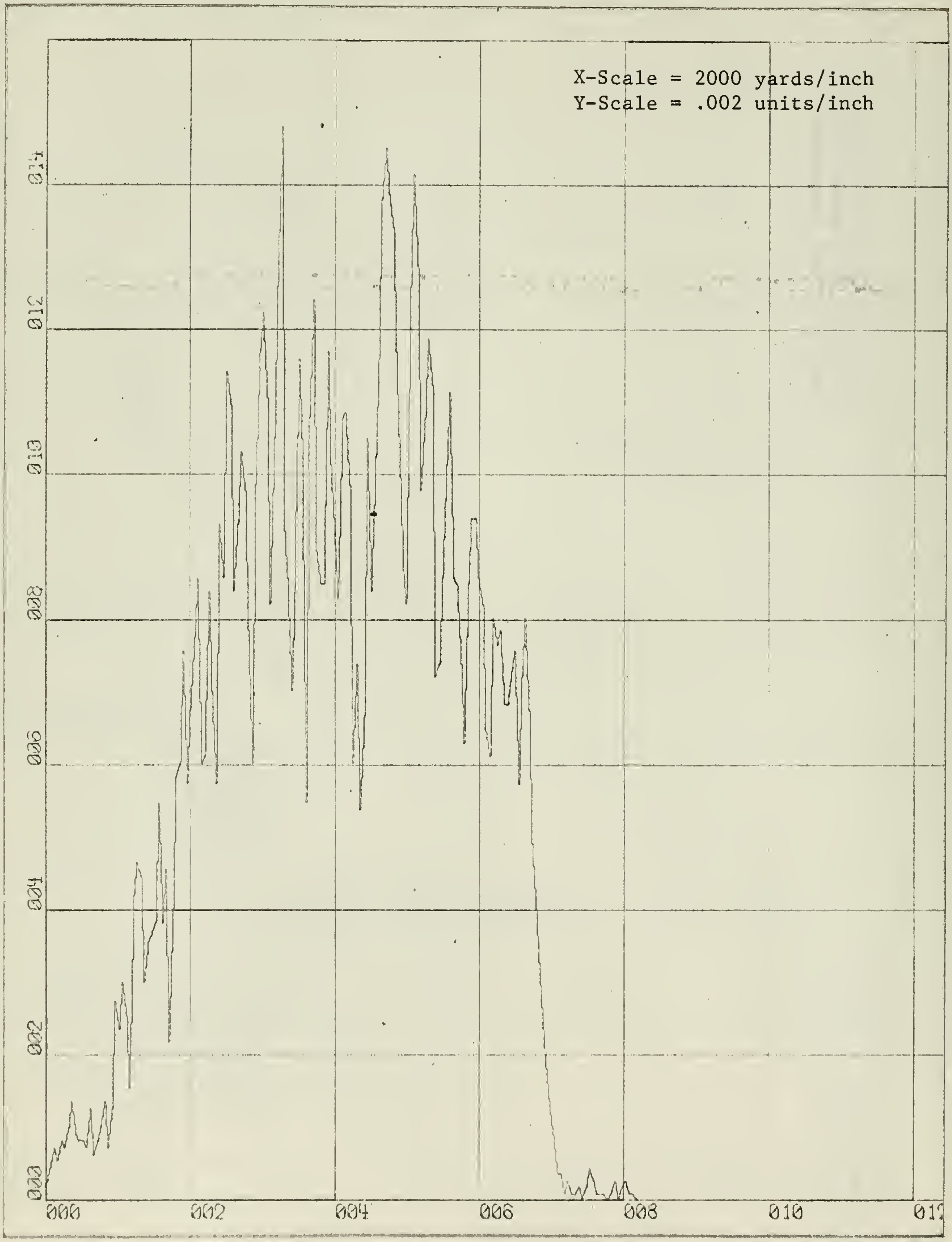

Figure 9. Mine Frequency Distribution on the Y-Axis for All Sample Runs.

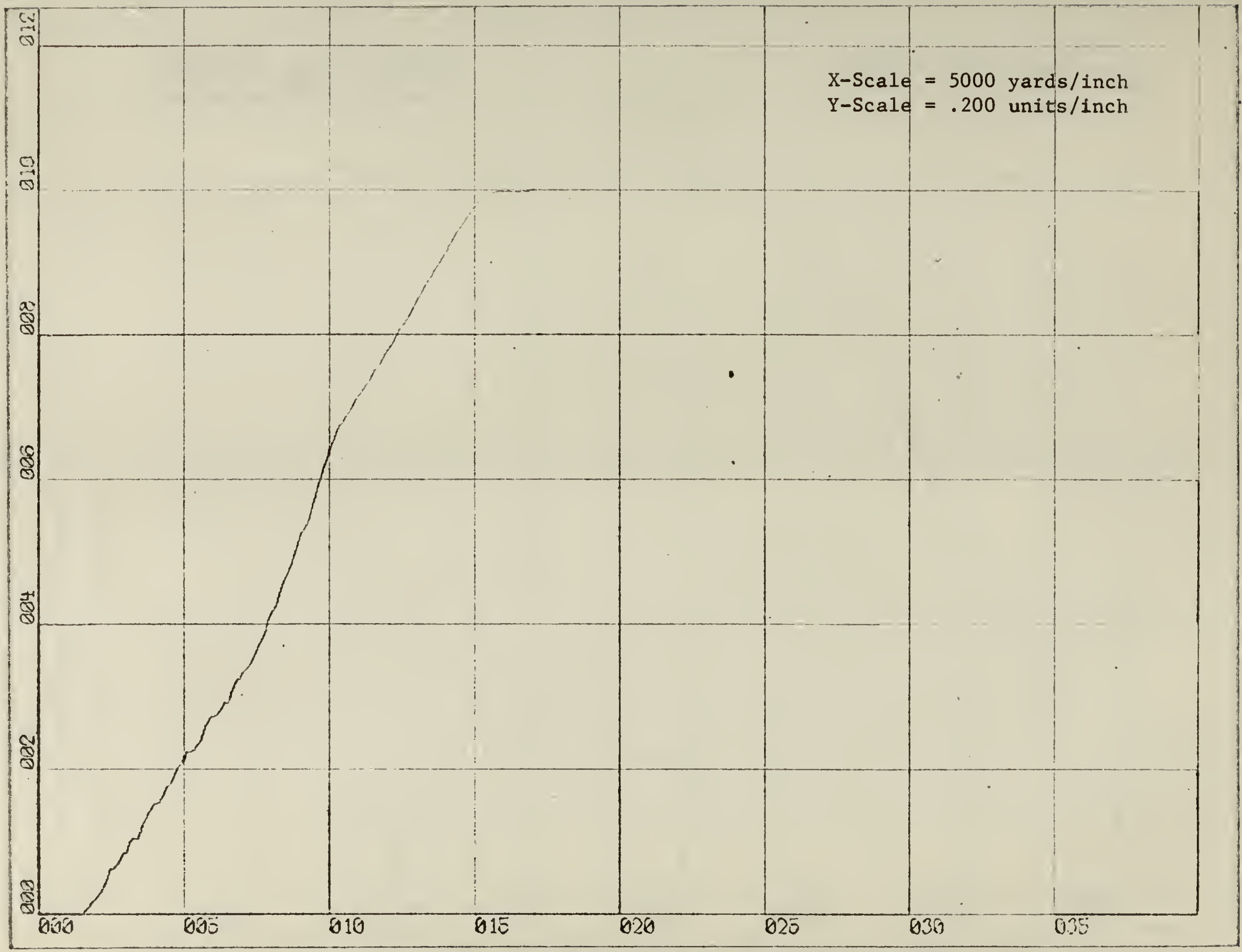

Figure 10. Mine Cumulative Distribution on the X-Axis for All Sample Runs.

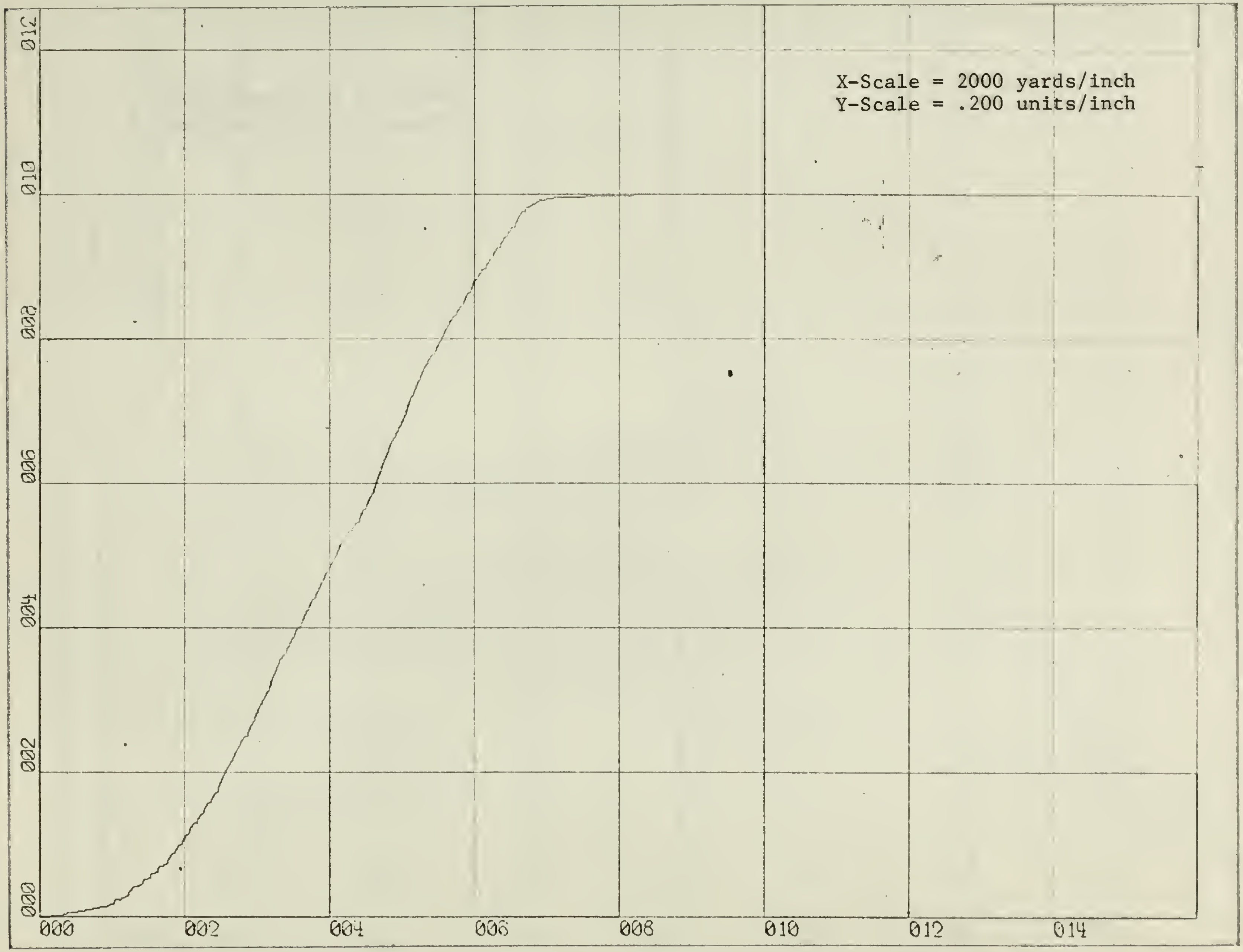

Figure 11. Mine Cumulative Distribution on the Y-Axis for All Sample Runs.

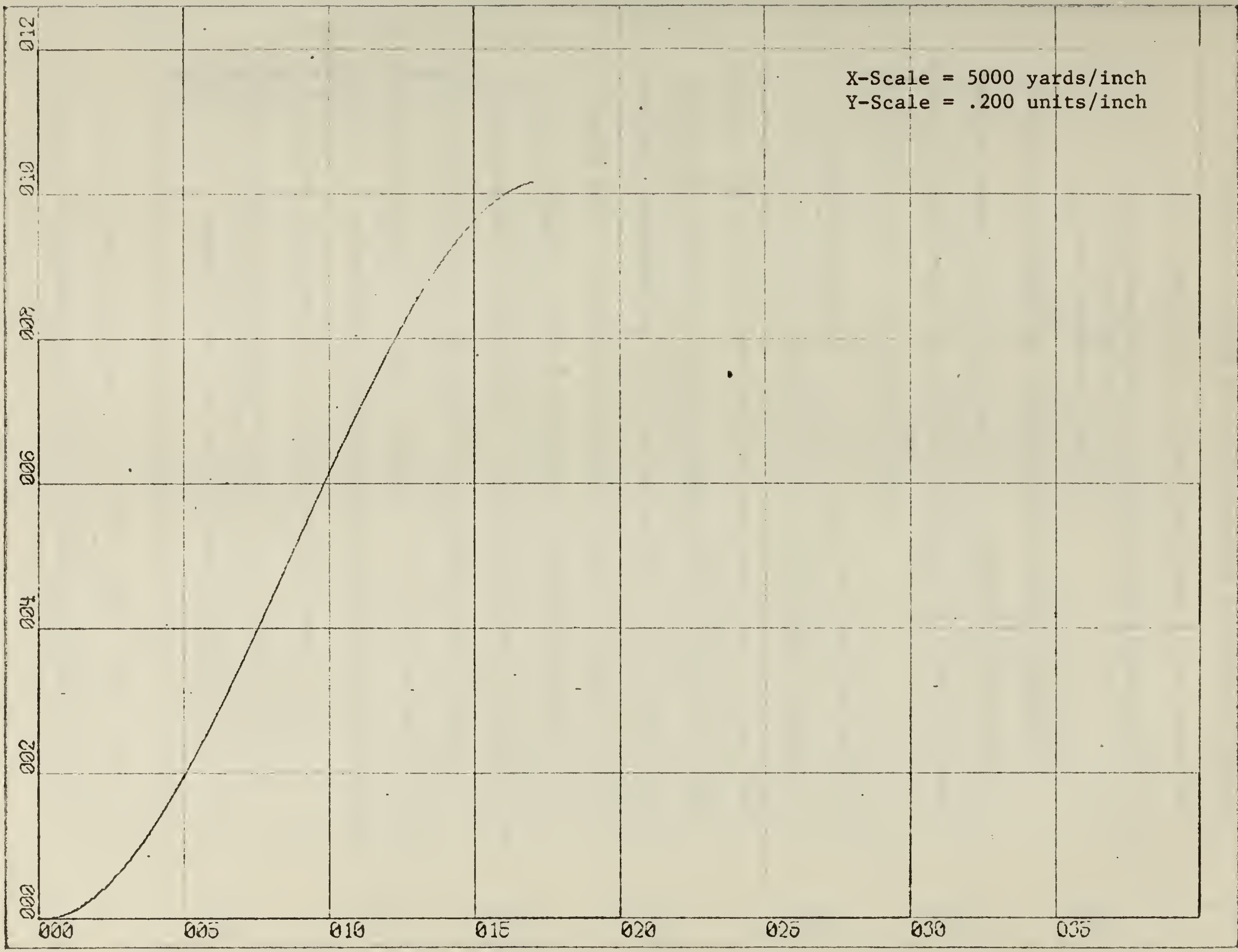

Figure 12. Least Squares Fit to Mine Cumulative Distribution Curve on the X-Axis for All Sample Runs.

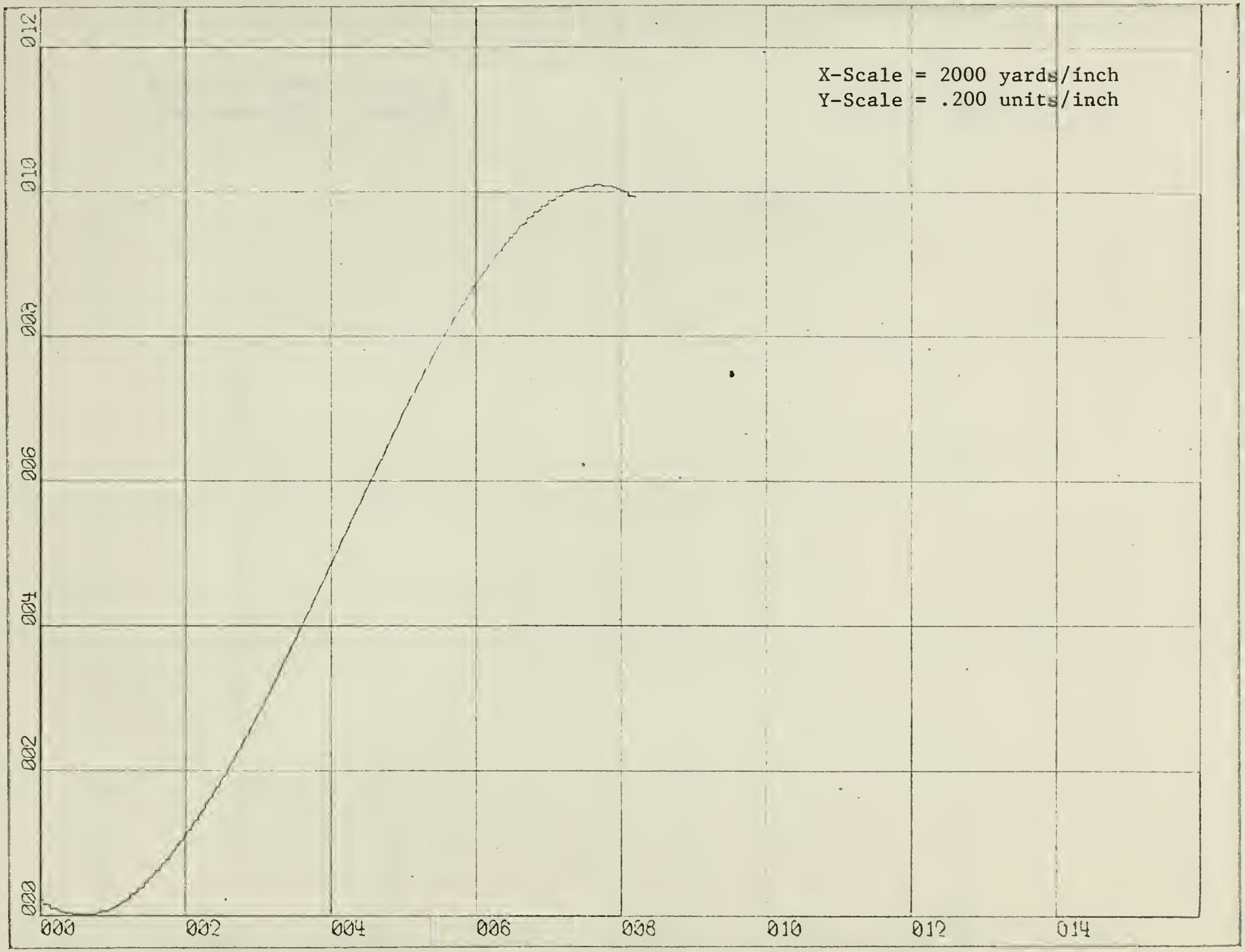

Figure 13. Least Squares Fit to Mine Cumulative Distribution Curve on Y-Axis for All Sample Runs.

vehicle mine load. This can not be simulated by random removal of mines from the intended minefield. The obvious "gaps" in the three sample minefields shown demonstrate the important effect of vehicle attrition on the final minefield pattern.

In view of the above and of the fact that consideration of vehicle capabilities is inherent to minefield planning and execution, there should be no doubt remaining that vehicle characteristics affect the final minefield.

Our primary objective of this model has been the generation of a "most probable" minefield for use by a threat assessment model. It was hoped that the data obtained from a large number of runs of this model could be analytically reduced to a single minefield representing the expected results of the execution of a mining plan. It has been suggested that this could be accomplished by defining the mine position distributions on two reference axes of the minefield. This approach was investigated and the results of using the observed distributions to generate a random minefield are shown in Figure 14. It is obvious upon comparison of the randomly generated pattern with the intended and other sample patterns that this approach is unsatisfactory. This general scheme can be improved upon, if the user is willing to expend the computer time and has the computer storage available, by developing several distributions on one axis, each of which is valid for a specified range on the other axis. Still unanswered, however, is the question of how many distributions on the one

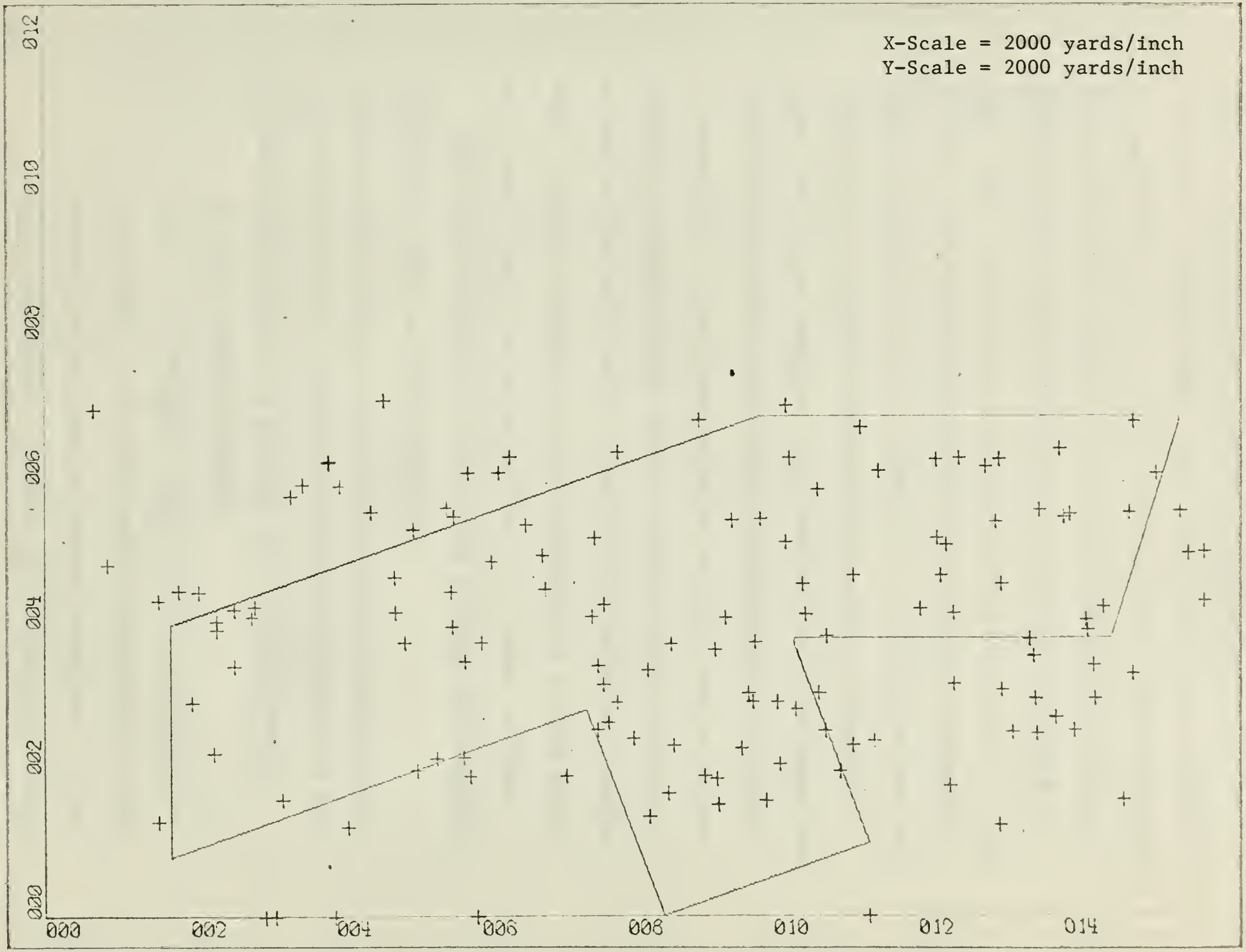

Figure 14. Randomly Generated Minefield Utilizing Distributions on the Axes.

axis would be required. It would appear that the number required is dependent on the minefield shape and the accuracy desired.

Regardless of the extent of the above approach, the basic problem of describing the "most probable" minefield remains unsolved. Each particular mine with its resultant parameters contributes in its own way to the minefield effectiveness and this has been ignored. Therefore, the mine position distribution approach is limited in application to those minefields consisting of similar type mines and where the physical environment of the mine is unimportant.

In view of the foregoing a procedure based on average minefield characteristics is recommended as an improved approximation to a "most probable" minefield. This procedure involves the selection of a sample number of runs from a large number of runs for threat assessment. While the results of no single run of program MINDEL could be considered truly representative of the "most probable" minefield, a sample consisting of those runs having characteristics approximating the expected or average characteristics of a large number of runs may be considered adequate for threat assessment purposes. For example, the Summary of Results in Appendix XIII shows for the test run of 80 iterations that the average number of mines layed was 137 of the 167 intended. Using the criterion of selecting the fields for which the number of mines layed was within plus or minus two of the average number of mines layed, runs number 11, 13, 16, 17, 34, 45, 50, 52, and 53 are selected. If the same criterion is applied to the number of effective mines, runs number 11, 16, 34, and 45 are eliminated. Again applying this criterion to the last three statistics in turn, run number 17 becomes the primary candidate for threat assessment. To obtain a larger sample size requires only relaxing the selection criterion accordingly. Having thus determined the minefield(s) to be used for threat assessment, the user has available in the output of program MINDEL1 the mine parameters of each mine layed in the selected run(s). Without these parameters, i.e., case depth, actuation sensitivity, actuation time, and mine type, in addition to the final mine position, the vehicle, mine, and bottom characteristics are not adequately represented.

It is concluded that the average values for the statistics shown in the Summary of Results Table (MINDEL1) provide the user with a convenient guide to the selection of the particular runs for threat assessment. While this is sampling via the "back-door", it circumvents the complexity of determining a true "most probable" minefield and yet preserves the consideration of individual mines in threat assessment.

Without further investigation into the area of defining the "most probable" minefield and in lieu of a more sophisticated minefield classification technique, it is recommended that the average statistics approach be adopted; since it represents a significant improvement over existing minefield generation techniques.

5. Conclusions and Recommendations.

It is concluded that:

1. The Mine Delivery Model provides the U. S. Navy with the capability of simulating specific mining plans.

2. Certain features incorporated in this model, i.e., bottom contour and bottom type, provide new flexibility in minefield generation.

3. Vehicle characteristics, particularly attrition and navigational capabilities, have decided effects on the final minefield.

4. The generation of minefields for threat assessment by simple probabilities for mine positions has limited applicability.

It is recommended that:

1. This model be adopted for use by the mine warfare modeling community.

2. The limitations of the use of simple probability distributions in generating mine positions for minefield threat assessment be recognized, and that this method be used accordingly.

3. Further investigation be conducted into the feasibility of classifying the "most probable" minefield.

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APPENDIX I

PROGRAM GRID

One of the first steps in the process of generating data for the Mine Delivery Model is the planning of the physical characteristics of the minefield. This requires the determination of the geographical limits of the field, the geographical position of each mine which is to be layed in the field, and the geographical positions of reference points for the minelaying vehicles. Depending upon the size of the minefield (the number of mines to be layed in the minefield) the generation of this data, even in the form of latitude and longitude coordinates, can be a very time consuming process.

Although there is no way to avoid manual plotting of the minefield on a chart and recording the coordinates of each desired position, the user is relieved of the task of converting these coordinates to the more usable form of an X-Y grid measured in yards. This conversion is accomplished by program GRID and the converted data is stored on magnetic tape for later use.

GRID has been written as a separate main program primarily because it uses several thousand storage locations which would otherwise have to be allocated to program MINDEL. Secondly, the use of GRID as a separate program results in more efficient use of computer time when running parametric analyses with the main program (MINDEL).

Program GRID accepts input data on punched cards as latitude and longitude coordinates recorded to the nearest one-hundredth of a minute and converts this data to X-Y grid coordinates measured in yards from an inputed reference position (XREF, YREF). The converted data (all mine positions, reference positions, and field coordinates) is stored on magnetic tape and also printed out for the user as a visual check against errors in the input data.

A list of inputs for program GRID is provided in the following pages along with information pertaining to how this data is punched on the data cards. A description of how ACLDL, SHLDL, and SULDL are derived is given below.

The reference position for the conversion process is determined by enclosing the minefield and all vehicle reference points by a rectangle of whatever size is necessary. The point XREF, YREF is then the lower left hand corner of this rectangle. In other words, XREF, YREF is the origin of a cartesian coordinate system positioned so that the minefield and all reference points fall within the first quadrant.

This program will handle all geographical situations (i.e., the minefield straddles the equator, the prime meridian, or the 180 degree meridian) except the case where XREF or the longitude of a mine position falls exactly on the 180 degree meridian.

All north latitudes and east longitudes must be inputed as positive values. All south latitudes and west longitudes must be inputed as negative values.

The use of input data recorded to the nearest one-hundredth of a minute results in an accuracy of approximately plus or minus twenty yards in any converted position. It is felt that this is an acceptable accuracy figure in view of the user's inability to obtain more accurate position information from the average nautical charts used for minefield planning purposes.

In the conversion process the inputed data is first converted to degrees and fractions of degrees and then converted to yards using the following equations[2], where each equation is divided by 0.9144 to convert from meters to yards.

Y = YLAT/57.29578

YINT = Y Latitude - YREF

XINT = X Longitude - XREF

To convert latitude:

Y(yds) =

$$\frac{((111132.09-566.05*COSF(2.0*Y)+1.20*COSF(4.0*Y))*YINT}{0.9144}$$

To convert longitude:

X(yds) =

$$\frac{((111415.10*COSF(Y)-94.55*COSF(3.0*Y)-.12*COSF(5.0*Y))*XINT}{0.9144}$$

If the user does not desire to utilize all three types of vehicles for laying a minefield, GRID will convert the desired

[2]N. Bowditch, American Practical Navigator (U. S. Navy Hydrographic Office Publication No. 9, 1958), p. 1187.

data if the appropriate parameters are inputed as zeroes. For example: if only aircraft and ships are to be used, NSUR, NSUC, and NMSU must be inputed as zeroes.

ACLDL, SHLDL, and SULDL are the primary inputs to program GRID, and the desired data for these matrices must be carefully recorded. Figures 15 and 16 illustrate the suggested formats for preparing this data prior to punching it on cards.

The following discussion relates to the preparation of data for ACLDL and/or SHLDL (reference figure 15).

Assume that the minefield and all mines have been plotted. Due to the large number of mines per leg shown here, it is reasonable to assume that these 271 mines are to be delivered by ships. Assume, also, that the legs have been determined, as well as the initial and terminal points for each leg (each leg must have an IP and a TP). There are 18 legs (column 1) to be transited by whatever number of ships have been assigned to the minelaying mission (one vehicle can transit more than one leg - the only limit to the number of legs per vehicle is the number of mines that the vehicle can carry). The number of mines to be layed on each leg is entered in column two. The X-coordinate of the IP for each leg is entered in column three and the Y-coordinate of each leg IP is entered in column four.

The number of the first mine to be layed on each leg is entered in column five, and this is followed by the X-coordinate and Y-coordinate of the intended position of that mine in columns six and seven. This sequence of "mine number, X-coordinate,

HIRCRAFT OR SHIP LEG DESCRIPTION LIST

Leg No.	No. of Mines	Initial Position X Coord.	Initial Position Y Coord.	Mine No.	Intended Position X Coord.	Intended Position Y Coord.	Mine No.	Intended P X Coord.	
1	30	-121.4517	36.4106	1	-121.4889	36.4106	2	-121.4930	
2	29	-121.5289	36.4089	31	-121.5243	36.4089	32	-121.5208	
3	14	-121.4888	36.4070	60	-121.4906	36.4080	61	-121.4949	
4	21	-121.5150	36.4048	74	-121.5124	36.4048	75	-121.5096	
5	7	-121.4856	36.4029	95	-121.4890	36.4029	96	-121.4921	
6	17	-121.5004	36.						

Intended Position X Coord.	Intended Position Y Coord.	Mine No.	Intended Position X Coord.	Intended Position Y Coord.
-121.5210	36.4106	30	-121.5264	36.4106
-121.4916	36.4089		-121.4902	36.4089

16	24	-121.5216	36.3814	244	-121.5194	36.3814	245	-121.5182	36.3814	246	-121.5167	36.3814	247	-121.5142	36.
17	3	-121.4635	36.3802	268	-121.4648	36.3802	269	-121.4681	36.3802	270	-121.4698	36.3802		-121.4712	36.3
18	1	-121.4704	36.3756	271	-121.4650	36.3756		-121.4642	36.3756						

figure 15.

Y-coordinate," is continued across each row from column five on until all mines and their positions for each particular leg have been entered (the maximum number of mines which can be layed on a leg is 31 without a modification to the program). Following the last mine position, the X-coordinate and Y-coordinate of the leg terminal point are recorded under the next "intended position" columns with the column for the mine number left blank. This procedure is illustrated in rows 2, 17, and 18 of Figure 15.

The procedure for recording data for the SULDL matrix (reference Figure 16) is similar to that above with the exception of the firing position. For self-propelled mines the firing position coordinates and the mine intended position coordinates must be different, while they will be the same for mines not self-propelled. When recording terminal point data for SULDL, the X-coordinate and Y-coordinate of the terminal point are recorded in the firing position columns with the mine number column again left blank. This procedure is illustrated in row three of Figure 16. The maximum number of mines which can be layed on one submarine leg is 18, but this value can be increased by a program change. Note that of the mines shown in Figure 16, mines number 65, 66,and 81 are self-propelled.

Figures 15 and 16 also illustrate the numerical format for the data which is to be punched on cards. The latitude value, for example, of 36 degrees and 25.48 minutes is punched as 36.2548. The same format is used for longitude values. The negative values shown in Figures 15 and 16 indicate West longitude as explained above.

SUBMARINE LEG DESCRIPTION LIST

Leg No.	No. of Mines	Initial Position		Mine No.	Firing Position		Intended Position		Mine No.	Firing Position		Intended Position		Mi. N.
		X Coord.	Y Coord.		X Coord.	Y Coord.	X Coord.	Y Coord.		X Coord.	Y Coord.	X Coord.	Y Coord.	
1	11	-121.5409	36.4070	65	-121.5361	36.3976	-121.5340	36.3829	66	-121.5342	36.3935	-121.5316	36.3784	6
2	5	-121.5201	36.3918	76	-121.5226	36.3909	-121.5226	36.3909	77	-121.5252	36.3899	-121.5252	36.3899	7
3	1	-121.5382	36.4157	81	-121.5362	36.4118	-121.5378	36.3917.		-121.5312	36.3992			
4	4	-121.5292	36.3938	82	-121.5262	36.3935	-121.5262	36.3935	83	-121.5242	36.3933	-121.5242	36.3933	8
5	7	-121.5211	36.3931	86	-121.5240	36.3945	-121.5240	36.3945	87	-121.525				

Figure 1.6

Immediately preceding the program listing which appears at the end of this appendix is presented a list of variables and input preparation guidelines for program GRID. The guidelines consist of a description of each data card in the order they should appear in the data deck. For each card a sample FORTRAN card strip punched with letters is shown followed by four columns; the first column is the letter key corresponding to the letters on the card strip and the second column is the corresponding FORTRAN specifications succeeded by the variable names as they appear in the program and a brief definition.

PROGRAM GRID - INPUT VARIABLES

FIRST DATA GROUP (ONE CARD)

```
AAAAABBBBBCCCCCDDDDDEEEEEFFFFFGGGGGHHHHHIIIIIJJJJJ
```

C ← FOR COMMENT | STATEMENT NUMBER | CONTINUATION | FORTRAN STATEMENT | IDENTIFICATION

```
A.     I5     NF     THE NUMBER OF POINTS DEFINING THE MINEFIELD
                     PERIMETER (MUST BE THE SAME AS THE NUMBER OF
                     ENTRIES IN FXPTS AND FYPTS).
B.     I5     NACR   THE NUMBER OF ROWS IN ACLDL.
C.     I5     NACC   THE NUMBER OF COLUMNS IN ACLDL.
D.     I5     NSHR   THE NUMBER OF ROWS IN SHLDL.
E.     I5     NSHC   THE NUMBER OF COLUMNS IN SHLDL.
F.     I5     NSUR   THE NUMBER OF ROWS IN SULDL.
G.     I5     NSUC   THE NUMBER OF COLUMNS IN SULDL.
H.     I5     NMA    THE NUMBER OF AIRCRAFT LAYED MINES.
I.     I5     NMS    THE NUMBER OF SHIP LAYED MINES.
J.     I5     NMSU   THE NUMBER OF SUBMARINE LAYED MINES.
```

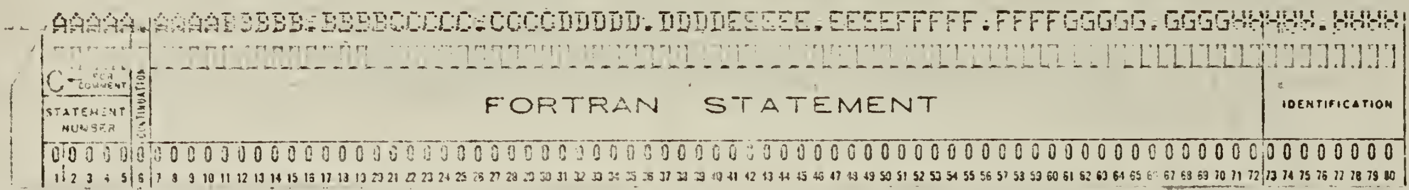
SECOND DATA GROUP (MAXIMUM OF 3 CARDS)

```
AAAAA.AAAABBBBB.BBBBCCCCC.CCCCDDDDD.DDDDEEEEE.EEEEFFFFF.FFFFGGGGG.GGGGHHHHH.HHHH
```

C ← FOR COMMENT | STATEMENT NUMBER | CONTINUATION | FORTRAN STATEMENT | IDENTIFICATION

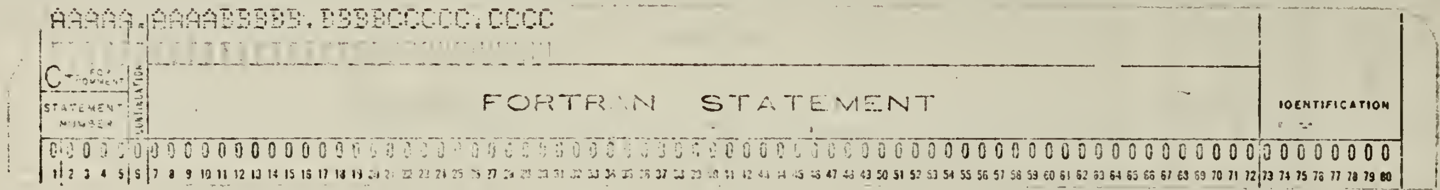
```
A-H.   F10.4  FXPTS  FIELD POINT VALUES - ELEMENTS OF FXPTS MATRIX.
```

THIRD DATA GROUP (MAXIMUM OF 3 CARDS)



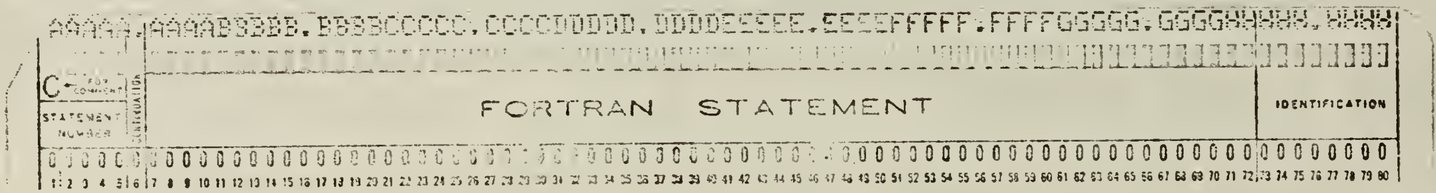
A-H. F10.4 FYPTS FIELD POINT VALUES - ELEMENTS OF FYPTS MATRIX.

FOURTH DATA GROUP (ONE CARD)



A. F10.4 XREF THE X-COORDINATE OF THE MINEFIELD REFERENCE POINT.
B. F10.4 YREF THE Y-COORDINATE OF THE MINEFIELD REFERENCE POINT.
C. F10.4 YLAT THE MEAN LATITUDE OF THE MINEFIELD.

FIFTH DATA GROUP (MAXIMUM OF 250 CARDS)



A-H. F10.4 ACLDL ELEMENTS OF ACLDL MATRIX ENTERED BY COLUMNS. I.E, THIS DATA MUST BE ENTERED AS ((ACLDL(I,J),I=1,NACR), J=1,NACC).

SIXTH DATA GROUP (MAXIMUM OF 250 CARDS)

```
AAAAA.AAAABBBBB.BBBBCCCCC.CCCCDDDDD.DDDDEEEEE.EEEEFFFFF.FFFFGGGGG.GGGGHHHHH.HHHH
```

C ← FOR COMMENT / STATEMENT NUMBER	CONTINUATION	FORTRAN STATEMENT	IDENTIFICATION
1 2 3 4 5	6	7 – 72	73 – 80

A-H. F10.4 SHLDL ELEMENTS OF SHLDL MATRIX ENTERED BY COLUMNS. I.E, THIS DATA MUST BE ENTERED AS ((SHLDL(I,J),I=1,NSHR), J=1,NSHC).

SEVENTH DATA GROUP (MAXIMUM OF 250 CARDS)

```
AAAAA.AAAABBBBB.BBBBCCCCC.CCCCDDDDD.DDDDEEEEE.EEEEFFFFF.FFFFGGGGG.GGGGHHHHH.HHHH
```

C ← FOR COMMENT / STATEMENT NUMBER	CONTINUATION	FORTRAN STATEMENT	IDENTIFICATION
1 2 3 4 5	6	7 – 72	73 – 80

A-H. F10.4 SULDL ELEMENTS OF SULDL MATRIX ENTERED BY COLUMNS. I.E, THIS DATA MUST BE ENTERED AS ((SULDL(I,J),I=1,NSUR), J=1,NSUC).

```
      PROGRAM GRID
      DIMENSION ACLDL(20,100),SHLDL(20,100),SULDL(20,100),FXPTS(20),FYPT
     1S(20),XREF(1),YREF(1),YLAT(1),XIP(20),YIP(20),XTP(20),YTP(20),XPTS
     2(620),YPTS(620),XFP(360),YFP(360)
      COMMON ACLDL,SHLDL,SULDL,XPTS,YPTS,XFP,YFP
      READ 5,NF,NACR,NACC,NSHR,NSHC,NSUR,NSUC,NMA,NMS,NMSU
    5 FORMAT(10I5)
      READ 6,(FXPTS(I),I=1,NF)
    6 FORMAT(8F10.4)
      READ 7,(FYPTS(I),I=1,NF)
    7 FORMAT(8F10.4)
      READ 8,XREF,YREF,YLAT
    8 FORMAT(3F10.4)
      READ 9,((ACLDL(I,J),I=1,NACR),J=1,NACC)
    9 FORMAT(8F10.4)
      READ 10,((SHLDL(I,J),I=1,NSHR),J=1,NSHC)
   10 FORMAT(8F10.4)
      READ 11,((SULDL(I,J),I=1,NSUR),J=1,NSUC)
   11 FORMAT(8F10.4)
      MFLAG=0
      CALL DEGCON(FXPTS,NF)
      CALL DEGCON(FYPTS,NF)
      CALL DEGCON(XREF,1)
      PRINT 26,XREF
   26 FORMAT(24H X REFERENCE POSITION IS,F10.3/)
      CALL DEGCON(YREF,1)
      PRINT 27,YREF
   27 FORMAT(24H Y REFERENCE POSITION IS,F10.3/)
      CALL DEGCON(YLAT,1)
      PRINT 29,YLAT
   29 FORMAT(17H MEAN LATITUDE IS,F10.3//)
      PRINT 40
   40 FORMAT(62H THE FOLLOWING COLUMN TITLES PERTAIN TO ALL DATA WHICH F
     1OLLOWS//)
      PRINT 41
   41 FORMAT(13H POSITION NO.,9X,8H X COORD,7X,8H Y COORD//)
```

```
      PRINT 45
   45 FORMAT(18H FIELD COORDINATES//)
      CALL CONVER(FXPTS,FYPTS,XREF(1),YREF(1),NF,YLAT(1),MFLAG)
      PRINT 97
   97 FORMAT(31H AIRCRAFT LEG INITIAL POSITIONS//)
      CALL CHANGE1(ACLDL,NACR,XREF(1),YREF(1),YLAT(1),XIP,YIP,MFLAG)
      PRINT 96
   96 FORMAT(29H AIRCRAFT LEG TERMINAL POINTS//)
      CALL CHANGE2(ACLDL,NACC,NACR,XREF(1),YREF(1),YLAT(1),NMA,XIP,YIP,M
     1FLAG)
      PRINT 95
   95 FORMAT(27H SHIP LEG INITIAL POSITIONS//)
      CALL CHANGE1(SHLDL,NSHR,XREF(1),YREF(1),YLAT(1),XIP,YIP,MFLAG)
      PRINT 80
   80 FORMAT(25H SHIP LEG TERMINAL POINTS//)
      CALL CHANGE2(SHLDL,NSHC,NSHR,XREF(1),YREF(1),YLAT(1),NMS,XIP,YIP,M
     1FLAG)
      PRINT 620
  620 FORMAT(//32H SUBMARINE LEG INITIAL POSITIONS //)
      CALL CHANGE1(SULDL,NSUR,XREF(1),YREF(1),YLAT(1),XIP,YIP,MFLAG)
      K = 1
      L = 1
      M = NSUC - 1
      DO 670 I = 1,NSUR
      DO 680 J = 6,M,5
      IF(SULDL(I,J-1))681,681,682
  681 XTP(L) = SULDL(I,J)
      L = L + 1
      GO TO 670
  682 XFP(K)=SULDL(I,J)
      XPTS(K) = SULDL(I,J+2)
  680 K = K + 1
  670 CONTINUE
      K = 1
      L = 1
      DO 770 I = 1,NSUR
      DO 780 J = 7,NSUC,5
```

```
      IF(SULDL(I,J-2))781,781,782
  781 YTP(L)=SULDL(I,J)
      L = L + 1
      GO TO 770
  782 YFP(K)=SULDL(I,J)
      YPTS(K) = SULDL(I,J+2)
  780 K = K + 1
  770 CONTINUE
      CALL DEGCON(XTP,NSUR)
      CALL DEGCON(YTP,NSUR)
      PRINT 785
  785 FORMAT(30H SUBMARINE LEG TERMINAL POINTS //)
      CALL CONVER(XTP,YTP,XREF(1),YREF(1),NSUR,YLAT(1),MFLAG)
      CALL DEGCON(XPTS,NMSU)
      CALL DEGCON(YPTS,NMSU)
      CALL DEGCON(XFP,NMSU)
      CALL DEGCON(YFP,NMSU)
      MFLAG=1
      CALL CONVER(XPTS,YPTS,XREF(1),YREF(1),NMSU,YLAT(1),MFLAG)
      CALL CONVER(XFP,YFP,XREF(1),YREF(1),NMSU,YLAT(1),MFLAG)
      PRINT 790
  790 FORMAT(//20H SUBMARINE MINE DATA //)
      PRINT 791
  791 FORMAT(13H POSITION NO.,4X,15HFIRING POSITION,8X,22HMINE INTENDED
     1POSITION /14X,47H XCOORD          YCOORD          XCOORD          YCOORD
     2//)
      DO 800 K=1,NMSU
      PRINT 810, K,XFP(K),YFP(K),XPTS(K),YPTS(K)
  810 FORMAT(4X,I3,6X,F11.3,F11.3,5X,F11.3,F11.3)
  800 CONTINUE
      DO 870 I=1,NSUR
      SULDL(I,3) = XIP(I)
  870 SULDL(I,4) = YIP(I)
      L = 1
      K = 1
      M = NSUC-1
```

```
      DO 820 I=1,NSUR
      DO 830 J=6,M,5
      IF(SULDL(I,J-1))831,831,832
  831 SULDL(I,J)=XTP(L)
      L = L + 1
      GO TO 820
  832 SULDL(I,J)=XFP(K)
      SULDL(I,J+2)=XPTS(K)
      K = K + 1
  830 CONTINUE
  820 CONTINUE
      L = 1
      K = 1
      DO 840 I=1,NSUR
      DO 850 J=7,NSUC,5
      IF(SULDL(I,J-2))851,851,852
  851 SULDL(I,J)=YTP(L)
      L = L + 1
      GO TO 840
  852 SULDL(I,J)=YFP(K)
      SULDL(I,J+2)=YPTS(K)
      K = K + 1
  850 CONTINUE
  840 CONTINUE
      WRITE TAPE 2,NF,NACR,NACC,NSHR,NSHC,NSUR,NSUC,XREF,YREF,(FXPTS(I),
     1I=1,NF),(FYPTS(I),I=1,NF),((ACLDL(I,J),I=1,NACR),J=1,NACC),((SHLDL
     2(I,J),I=1,NSHR),J=1,NSHC),((SULDL(I,J),I=1,NSUR),J=1,NSUC)
      END
```

```
      SUBROUTINE CHANGE1(A,N,P,Q,R,XIP,YIP,MM)
      DIMENSION A(20,100),XIP(20),YIP(20)
      DO 46 J=1,N
   46 XIP(J)=A(J,3)
      DO 47 K=1,N
   47 YIP(K)=A(K,4)
      CALL DEGCON(XIP,N)
      CALL DEGCON(YIP,N)
      CALL CONVER(XIP,YIP,P,Q,N,R,MM)
      RETURN
      END
```

```
      SUBROUTINE CHANGE2(A,N1,N2,P,Q,R,M1,XIP,YIP,MMM)
      DIMENSION A(20,100),XTP(20),YTP(20),XPTS(620),YPTS(620),XIP(20),YI
     1P(20)
      K=1
      L=1
      M=N1-1
      DO 70 I=1,N2
      DO 80 J=6,M,3
      IF(A(I,J-1))81,81,82
   81 XTP(L)=A(I,J)
      L=L+1
      GO TO 70
   82 XPTS(K)=A(I,J)
   80 K=K+1
   70 CONTINUE
      K=1
      L=1
      DO 170 I=1,N2
      DO 180 J=7,N1,3
      IF(A(I,J-2))181,181,182
  181 YTP(L)=A(I,J)
      L=L+1
      GO TO 170
  182 YPTS(K)=A(I,J)
  180 K=K+1
  170 CONTINUE
      CALL DEGCON(XTP,N2)
      CALL DEGCON(YTP,N2)
      CALL CONVER(XTP,YTP,P,Q,N2,R,MMM)
      PRINT 500
  500 FORMAT(15H MINE POSITIONS//)
      CALL DEGCON(XPTS,M1)
      CALL DEGCON(YPTS,M1)
      CALL CONVER(XPTS,YPTS,P,Q,M1,R,MMM)
      DO 400 I=1,N2
      A(I,3)=XIP(I)
```

```
  400 A(I,4)=YIP(I)
      L=1
      K=1
      M=N1-1
      DO 410 I=1,N2
      DO 420 J=6,M,3
      IF(A(I,J-1))421,421,422
  421 A(I,J)=XTP(L)
      L=L+1
      GO TO 410
  422 A(I,J)=XPTS(K)
      K=K+1
  420 CONTINUE
  410 CONTINUE
      L=1
      K=1
      DO 510 I=1,N2
      DO 520 J=7,N1,3
      IF(A(I,J-2))521,521,522
  521 A(I,J)=YTP(L)
      L=L+1
      GO TO 510
  522 A(I,J)=YPTS(K)
      K=K+1
  520 CONTINUE
  510 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DEGCON(A,N)
      DIMENSION A(620)
      DO 100 L=1,N
      IF(A(L))101,100,102
  101 LFLAG=0
      GO TO 110
  102 LFLAG=1
  110 CALL FRACT(A,L,LFLAG)
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINF FRACT(A,M,LF)
      DIMENSION A(620)
      A(M)=ABSF(A(M))
      LA=A(M)
      FLPT=LA
      REM=DIMF(A(M),FLPT)
      ADD=REM/0.6
      A(M)=FLPT+ADD
      IF(LF)115,115,116
  115 A(M)=-A(M)
  116 RETURN
      END
```

```
      SUBROUTINE CONVER(A,B,C,D,N,YDEG,M)
      DIMENSION A(620),B(620)
      Y=YDEG/57.29578
      DO 5 I=1,N
      YINT=B(I)-D
      B(I)=((111132.09-566.05*COSF(2.0*Y)+1.20*COSF(4.0*Y))*YINT)/.9144
    5 CONTINUE
    6 DO 7 J=1,N
      IF(C) 10,11,11
   10 XINT=A(J)-C
      GO TO 20
   11 IF(A(J))10,13,13
   13 DXDT=180.000+A(J)
      X=180.000-C
      XINT=DXDT+X
   20 A(J)=((111415.10*COSF(Y)-94.55*COSF(3.0*Y)-.12*COSF(5.0*Y))*XINT
     1)/.9144
    7 CONTINUE
      IF(M)50,50,60
   50 DO 30 K=1,N
      PRINT 21,K,A(K),B(K)
   21 FORMAT(4X,I3,12X,F11.3,6X,F11.3)
   30 CONTINUE
   60 RETURN
      END
```

APPENDIX II

PROGRAM SURFIT

The final position of a mine is of great importance to this model not only because the determination of this position is one of the primary objectives of the model, but because it plays a vital role in determining other characteristics of the mine.

When any mine is layed its characteristics are dependent upon (1) whether it is operable or not, and (2), if it is operable, its physical environment. The question of mine operability is, among other things, decided by whether or not the mine is damaged on bottom impact. This in turn is a function of the type of bottom the mine impacts upon. The question of the physical environment of the mine is decided by whether or not the mine buries and the final water depth of the mine case.

In order to provide a ready reference of data for answering these questions over the continuum of possible final mine positions in the minefield area program SURFIT is used. This program fits, in the least squares sense, a polynomial function, Z, of two independent variables, X and Y, to values of the dependent variable specified at points on a rectangular grid in the plane of the independent variables. That is, given a set of values of Z at points of the X, Y grid, the program finds the polynomial

$$Z = \sum_{n=0}^{N} \sum_{m=0}^{M} A_{n,m} X^n Y^m$$ which best fits the data.

The optimum values of N and M as well as the coefficients, $A_{n,m}$, are determined.

The same rectangle as was used to define the minefield area in program GRID is recommended for use here. This rectangle is then divided into a grid of 45 or less segments on each axis. The fineness of this grid should be determined by the user as necessary to adequately describe both the water depth variations and the bottom type variations (as explained in Appendix III).

When the water depth and bottom type data are prepared as described in the "Input Data" section, program SURFIT generates the coefficients of the depth contour and the bottom type contour polynomials. This information, along with the degrees of the independent variables in each polynomial, is written on magnetic tape for use in program MINDEL. A complete printout of all input data, the generated coefficients, and a table of differences is provided. The table of differences provides the user with the necessary information to determine the accuracy of the fit in each case. It should be noted that in the case of the depth contour any land masses within the rectangle must be given a negative depth gradient if an accurate fit is to be obtained.

Program SURFIT[3] was copied from the U. S. Naval Postgraduate School Computer Facility Library and modified slightly for use in this model. The program listing which appears at the end of this appendix is basically the original listing, although not all aspects of it are used. Specifically, that part of the program

[3]R. E. Clark, R. N. Kubik, and L. P. Phillips, "Orthogonal Polynomial Least Squares Surface Fit, Algorithm 164." <u>Communications of the ACM</u>, VI (April, 1963), pp. 162-163.

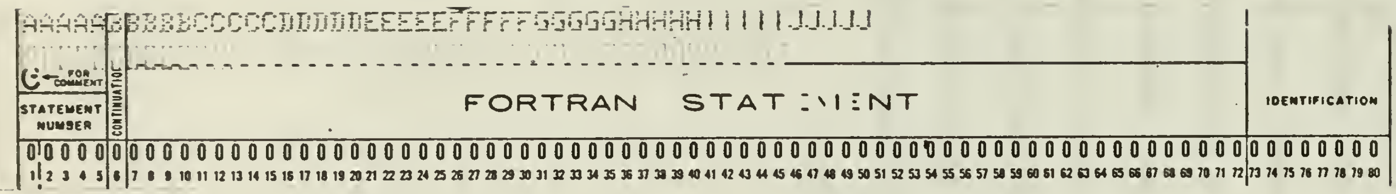
which pertains to new X and Y values that can be read in for evaluation after the polynomial has been calculated is not used in this program. The basic computational technique is used, however, in program MINDEL where it is included as Subroutine Depth.

The "Input Data" section which immediately follows describes the complete range of input data for program SURFIT as a convenience to the user. The description lists the punched cards in the order they are to appear in the data deck. For each card there is a sample FORTRAN card strip punched in the correct format with letters. In the four columns below each sample card strip may be found the letter keys corresponding to the letters on the card strip, the corresponding FORTRAN specifications, the variable names as they appear in the program, and a brief definition. The input variables which have been specifically used in this adaptation of program SURFIT are denoted by asterisks.

PROGRAM SURFIT

INPUT DATA

1. FIRST DATA CARD(*)

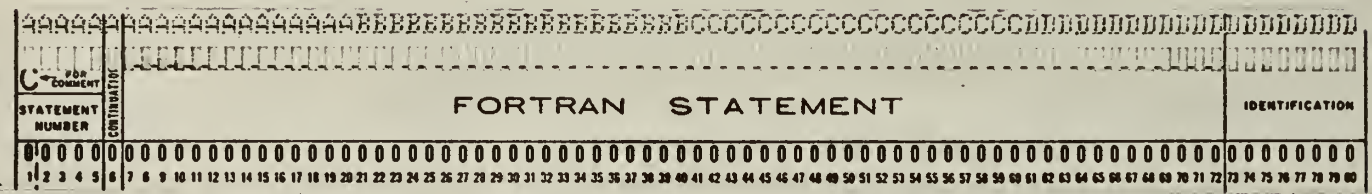


A.	I5	NMAX	THE MAXIMUM DEGREE OF X TO BE CONSIDERED(LESS THAN OR EQUAL TO IMAX).
B.	I5	MMAX	THE MAXIMUM DEGREE OF Y TO BE CONSIDERED(LESS THAN OR EQUAL TO JMAX).
C.	I5	IMAX	THE NUMBER OF X VALUES(LESS THAN OR EQUAL TO 45).
D.	I5	JMAX	THE NUMBER OF Y VALUES(LESS THAN OR EQUAL TO 45).
E.	I5	IEQX	A CONTROL PARAMETER. IF IEQX=0, ALL X VALUES WILL BE READ IN (SEE(2) SECOND DATA GROUP FOR FORMAT) IF IEQX=1,ONLY THE FIRST AND LAST VALUE OF X WILL BE READ IN AND THE PROGRAM GENERATES THE REMAINING EQUALLY SPACED X VALUES (SEE (3) SECOND DATA GROUP FOR FORMAT).
F.	I5	IEQY	A CONTROL PARAMETER WITH THE SAME FUNCTION AS IEQX FOR Y VARIABLES(SEE (4) AND (5) THIRD DATA CARD/GROUP FOR FORMAT).
G.	I5	KWT	A CONTROL PARAMETER. IF KWT=0, ALL WEIGHTS CORRESPONDING TO X AND Y VALUES ARE UNITY. IF KWT=1, THE U(I),WEIGHTS EACH CORRESPONDING TO A X(I), WILL BE READ IN, AND ALL WEIGHTS CORRESPONDING TO Y VALUES ARE CONSIDERED UNITY. IF KWT=2,THE W(J),WEIGHTS EACH CORRESPONDING TO A Y(J) WILL BE READ IN AND ALL WEIGHTS CORRESPONDING TO X(J) ARE CONSIDERED UNITY. IF KWT=3,THE U(I) AND W(J), REPRESENTING THE WEIGHTS CORRESPONDING TO X(I) AND Y(J) WILL BE READ IN(SEE FOURTH

```
                          DATA GROUP FOR FORMAT).
H.    I5     IFMT   A CONTROL PARAMETER. IF IFMT=0, THEN THE FORMAT USED TO READ
                    Z VALUES IS ASSUMED TO BE(4F20.0). IF IFMT=1, VARIABLE
                    FORMAT CARD WILL BE SUPPLIED BY THE USER(SEE(10) FIFTH DATA
                    CARD).
I.    I5     NEWCTL A CONTROL PARAMETER. IF NEWCTL=0, THEERE ARE NO NEW X AND Y
                    VALUES TO BE READ IN FOR EVALUATION AFTER THE POLYNOMIAL HAS
                    BEEN FOUND. IF NEWCTL=1, NEW X AND Y VALUES WILL BE READ IN
                    FOR EVALUATION(SEE (12),(13) SEVENTH,EIGHTH DATA GROUP FOR
                    FORMAT).
J.    I5     KODE   A CONTROL PARAMETER. IF KODE=1, AN ADDITIONAL COEFFICIENT
                    TABLE OF ORTHOGONAL POLYNOMIALS WILL BE PRINTED. FOR REGULAR
                    OUTPUT KODE=0.
NOTE-ALL FIXED POINT INTEGERS MUST BE RIGHT JUSTIFIED IN THEIR RESPECTIVE FIELDS
```

IF IEQX=0, THE FOLLOWING CARD(S) WILL BE READ.

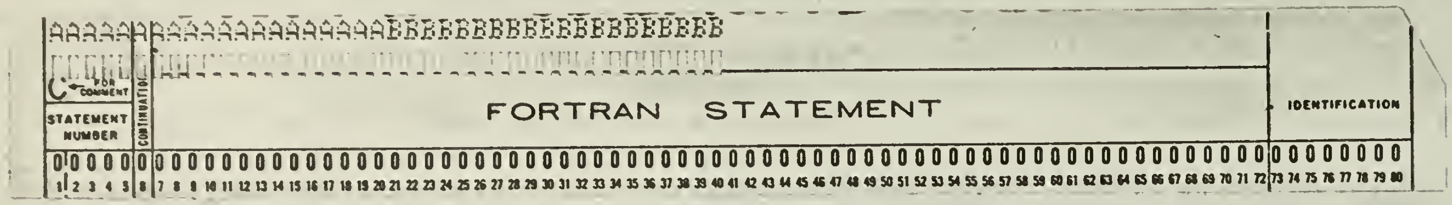
2. SECOND DATA GROUP (MAXIMUM OF 12 CARDS)



A-D. F20.0 X(I) IMAX ORIGINAL X VALUES.

IF IEQX=1, THE FOLLOWING CARD WILL BE READ.

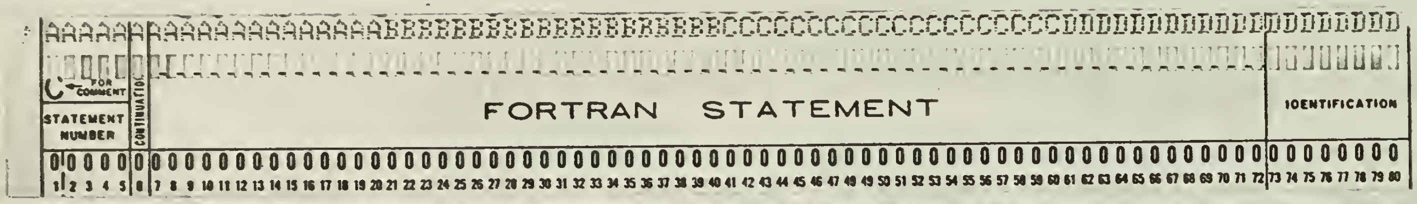
3. SECOND DATA CARD (*)



A. F20.0 XFIRST THE SMALLEST VALUE OF X.
B. F20.0 XLAST THE LARGEST VALUE OF X.

IF IEQY=0, THE FOLLOWING CARD(S) WILL BE READ.

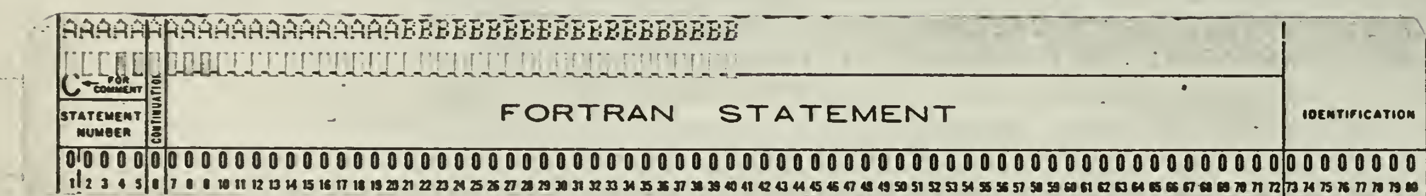
4. THIRD DATA GROUP (MAXIMUM OF 12 CARDS)



A-D. F20.0 Y(J) JMAX ORIGINAL Y VALUES.

IF IEQY=1, THE FOLLOWING CARD WILL BE READ.

5. THIRD DATA CARD (*)



A. F20.0 YFIRST THE SMALLEST VALUE OF Y.

B. F20.0 YLAST THE LARGEST VALUE OF Y.

IF KWT=0, NO CARD WILL BE READ FOR THIS GROUP (*)

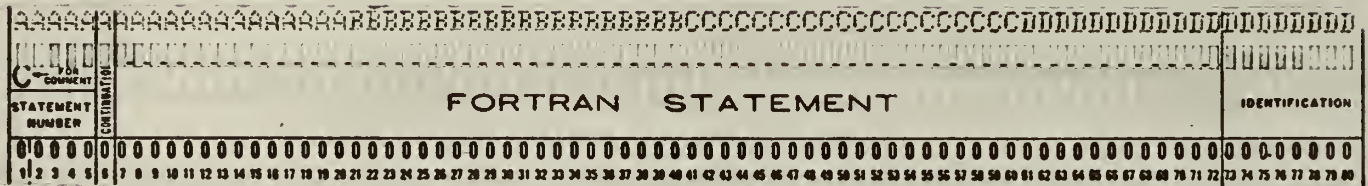
IF KWT=1, THE FOLLOWING CARD(S) WILL BE READ.

6. FOURTH DATA GROUP (MAXIMUM OF 12 CARDS)

A-D. F20.0 U(I) IMAX NUMBERS OF WEIGHTS CORRESPONDING TO THE X(I).

IF KWT=2, THE FOLLOWING CARD(S) WILL BE READ.

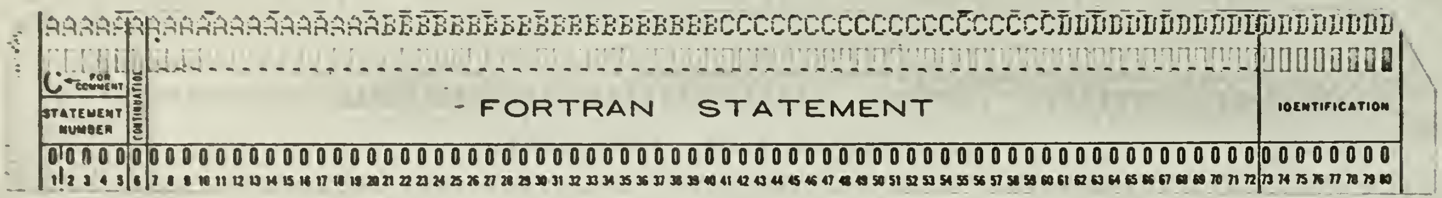
7. FOURTH DATA GROUP (MAXIMUM OF 12 CARDS)



A-D. F20.0 W(J) JMAX NUMBERS OF WEIGHTS CORRESPONDING TO THE Y(J).

IF KWT=3, THE FOLLOWING CARD(S) WILL BE READ.

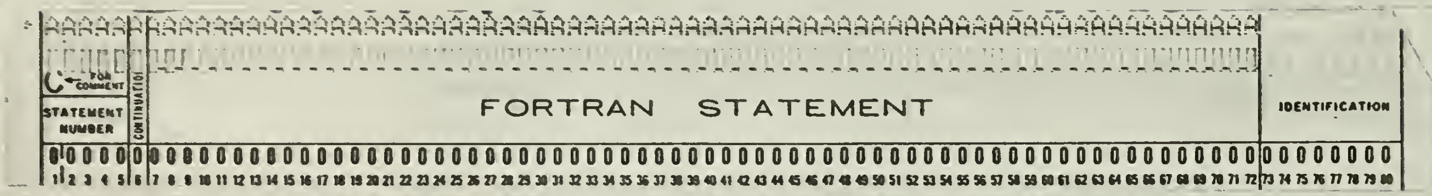
8. FOURTH DATA GROUP (MAXIMUM OF 24 CARDS)



A-D. F20.0 U(I), IMAX PLUS JMAX NUMBERS OF WEIGHTS CORRESPONDING TO THE X(I)
W(J) AND Y(J) VALUES.

IF IFMT=1, THE FOLLOWING CARD WILL BE READ.

9. FIFTH DATA CARD.



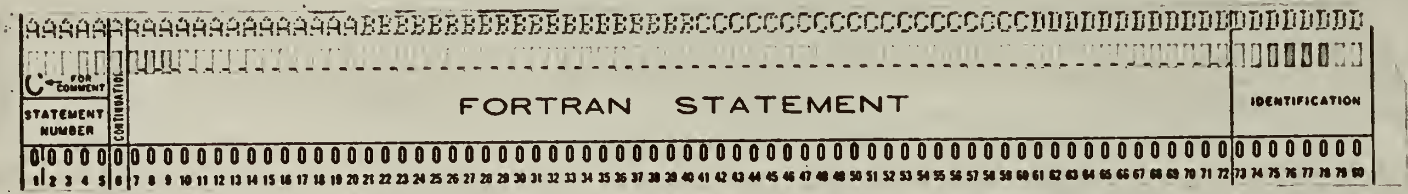
A. 10A8 IFMTZ A VARIABLE FORMAT CARD USED TO READ IN Z VALUES(SEE (10) SIXTH DATA GROUP).

10. SIXTH DATA GROUP

Z(I,J) IMAX TIMES JMAX ORIGINAL Z VALUES MUST APPEAR ON THE NEXT CARDS UNTIL (IMAX TIMES JMAX) OF THEM HAVE BEEN READ USING THE VARIABLE FORMAT SUPPLIED BY THE USER. THE Z MATRIX SHOULD BE PUNCHED ROW-WISE.

IF IFMT=0, THE FOLLOWING CARDS WILL BE READ.

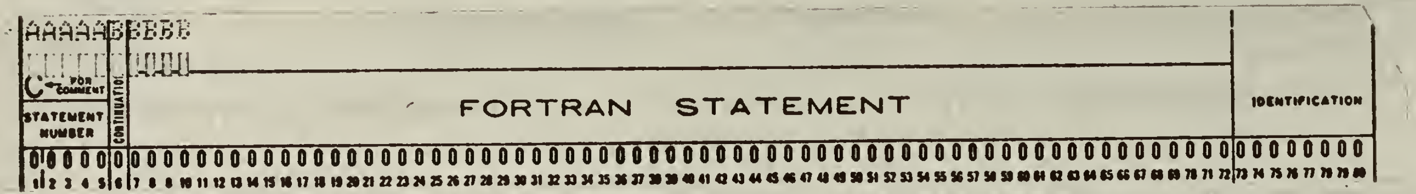
11. SIXTH DATA GROUP (MAXIMUM OF 507 CARDS) (*)



A-D. F 2.0 Z(I,J) (IMAX TIMES JMAX) ORIGINAL Z VALUES MUST APPEAR ON THE NEXT CARDS UNTIL (IMAX TIMES JMAX) OF THEM HAVE BEEN READ. THE Z MATRIX SHOULD BE PUNCHED ROW-WISE, USING AS MANY CARDS AS NECESSARY, WITHOUT INTERMEDIATE BLANK FIELDS. Z(1,1),Z(1,2),...,Z(1,JMAX),Z(2,1),Z(2,2),...,Z(2,JMAX),...,Z(IMAX,1),Z(IMAX,2),...,Z(IMAX,JMAX).

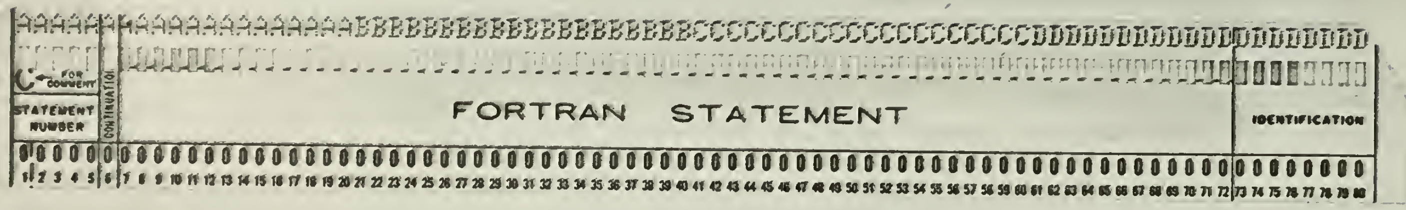
THE FOLLOWING CARDS ARE READ ONLY IF NEWCTL=1.

12. SEVENTH DATA CARD



A.	I5	NEWX	THE NUMBER OF NEW X VALUES(LESS THAN OR EQUAL TO 45).
B.	I5	NEWY	THE NUMBER OF NEW Y VALUES(LESS THAN OR EQUAL TO 45).

13. EIGHTH DATA GROUP




```
A-D.   F20.0   X(I),   NEWX PLUS NEWY NUMBERS OF NEW X VALUES AND NEW Y VALUES MUST
               Y(J)    APPEAR ON THE NEXT CARDS.
```

```
      PROGRAM SURFIT
      DIMENSION X(45),U(45),Y(45),W(45),Z(45,45),IFMTZ(10)
      DIMENSION FXPTS(10),FYPTS(10),ACLDL(8,31),SHLDL(7,70),SULDL(4,37)
C   NMAX=(DEGREE OF X) +1,MMAX=(DGR OF Y)+1, IMAX= NO.OF X ,JMAX= NO.OF Y
C   KODE=0 MINIMUM PRINTED OUTPUT , KODE=1 MAX PRINTED OUTPUT , KWT =0
C   ALL WEIGHTS =1 , KWT =1 READ IMAX NUMBERS OF U(I) WEIGHTS FOR X ,THEN
C   READ JMAX NUMBERS OF W(J) WEIGHTS FOR Y.
C   NEWCTL =1  READ NEXT CONTROL CARD FOR NEW X,Y TO BE READ IN FOR
C   EVALUATION AFTER THE SURFACE HAS BEEN FOUND. NEWCTL=0 NO NEW XANDY
      REWIND 2
      READ TAPE 2, NF,NACR,NACC,NSHR,NSHC,NSUR,NSUC,XREF,YREF,(FXPTS(I),
     1I=1,NF),(FYPTS(I),I=1,NF),((ACLDL(I,J),I=1,NACR),J=1,NACC),((SHLDL
     2(I,J),I=1,NSHR),J=1,NSHC),((SULDL(I,J),I=1,NSUR),J=1,NSUC)
      REWIND 2
      WRITE TAPE 2,NF,NACR,NACC,NSHR,NSHC,NSUR,NSUC,XREF,YREF,(FXPTS(I),
     1I=1,NF),(FYPTS(I),I=1,NF),((ACLDL(I,J),I=1,NACR),J=1,NACC),((SHLDL
     2(I,J),I=1,NSHR),J=1,NSHC),((SULDL(I,J),I=1,NSUR),J=1,NSUC)
      DO9999 INUM=1,2
      READ 50,NMAX,MMAX,IMAX,JMAX,IEQX,IEQY,KWT,IFMT ,NEWCTL,KODE
   50 FORMAT(10I5)
      MMAX=MMAX+1
      NMAX=NMAX+1
      IF(IEQX)  61,63,61
C   IEQX=0,ALL XS VALUE TO BE READIN ,IEQX=1, ONLY FIRST AND LAST VALUES
C   OF XS READ IN
   61 READ 51, XFIRST, XLAST
   51 FORMAT (4F20.0)
      XNUM = IMAX-1
      DELTAX = (XLAST-XFIRST) /XNUM
      II=IMAX-1
      X(1)= XFIRST
      DO 62 I=2,II
   62 X(I)= X(I-1)+DELTAX
      X(IMAX) = XLAST
      GO TO 64
   63 READ 51,(X(I),I=1,IMAX)
```

```
   64 IF (IEQY) 71,73,71
   71 READ 51,YFIRST,YLAST
      YNUM = JMAX-1
      DFLTAY = (YLAST -YFIRST)/ YNUM
      JJ= JMAX-1
      Y(1) =YFIRST
      DO 72  J=2,JJ
   72 Y(J)= Y(J-1)+DELTAY
      Y(JMAX)= YLAST
      GO TO 74
   73 READ 51,(Y(J),J=1,JMAX)
   74 IF (KWT)  75,79,75
   75 GO TO (76,77,78),KWT
C  KWT=0,NO WGT,=1 RDX WGT , =2, Y WGT , =3  X AND Y WGT
   76 READ 51,(U(I),I=1,IMAX)
      DO 176 J=1,JMAX
  176 W(J)=1.
      GO TO 80
   77 READ 51,(W(J),J=1,JMAX)
      DO 177 I=1,IMAX
  177 U(I)=1.
      GO TO 80
   78 READ 51,(U(I),I=1,IMAX)
      READ 51,(W(J),J=1,JMAX)
      GO TO 80
   79 DO 179 I=1,IMAX
  179 U(I)=1.
      DO 279 J=1,JMAX
  279 W(J)=1.
C  IF IFMT =0,USE REGULAR FORMAT,IF IFMTZ=1,READ1 VARIABLE FORMAT CARD
   80 IF (IFMT )  81,82,81
   82 READ 51, ((Z(I,J),J=1,JMAX),I=1,IMAX)
      GO TO 90
C  Z ALWAYS READ IN ROW WISE
   81 READ 181,IFMTZ
  181 FORMAT (10A8)
```

```
      READ IFMTZ, ((Z(I,J),J=1,JMAX),I=1,IMAX)
   90 CALL SURFACE (X,U,Y,W,Z,NMAX,MMAX,IMAX,JMAX,                CMINSQD,
     1CSUMDIF,CMAXDIF        ,NEWCTL,KODE)
 9999 CONTINUE
      END
```

```
      SUBROUTINE SURFACE(X,U,Y,W,Z,NMAX,MMAX,IMAX,JMAX,           CMINSQD,
     1CSUMDIF,CMAXDIF       ,NEWCTL,KODE)
      DIMENSION DENPA(45),DENQA(45),ALPHA(45,45),P(45,45),Q(45,45),
     1PC(45,45),QC(45,45),A(45),B(45),C(45),D(45),X(45),U(45),Y(45),
     2W(45),Z(45,45),BETA(45,45),PHI(45,45),ZCOMP(45,45)
     3,IFMTZ(10)
     4,ZDIFF(45,45)
      COMMON P,Q
      EQUIVALENCE(P,PC),(Q,QC) ,(ALPHA,ZCOMP)
      IF (IMAX-8)    3001,3001,3002
 3001 IF (JMAX-16)  3003,3003,3004
 3003 ICON= 1H0
      GO TO 3010
 3004 ICON =1H1
      GO TO 3010
 3002 IF (IMAX-16)  3005,3005,3004
 3005 IF (JMAX-10)  3003,3003,3004
C     PRINT INPUT DATA X,Y,AND Z
 3010 PRINT 2100
 2100 FORMAT(1H120X48HINPUT DATA INDEPENDENT  VARIABLES  X (I)
     1   //)
      PRINT2101,( X(I), I=1,IMAX )
 2101 FORMAT        (8E14.7)
      PRINT 2102
 2102 FORMAT( /// 20X 45H INPUT DATA INDEPENDENT  VARIABLES  Y (J)
     1   //)
      PRINT2101,(Y(J),J=1,JMAX)
      PRINT 3000
 3000 FORMAT (////)
      PRINT 2103,ICON
 2103 FORMAT(A1,20X         40HINPUT DATA  DEPENDENT  VARIABLES Z(I,J)
     1   /// )
      PRINT2105,(J, J=1,JMAX)
 2105 FORMAT(4H I/J I13,7I14 / (4X,I13,7I14))
      DO2106 I=1,IMAX
 2106 PRINT2107,I,(Z(I,J),J=1,JMAX)
```

```
 2107 FORMAT(// I3,8E14.7 /(3X8E14.7))
C NORMALIZATION OF VARIABLES
      SUMX=0.
      SUMY=0.
      SUMZ=0.
      DO 10 I=1,IMAX
   10 SUMX=SUMX+X(I)
      XIMAX=IMAX
      XMEANX= SUMX/XIMAX
      PRINT 1001,XMEANX
 1001 FORMAT(//10H XMEANX =      E20.10)
      DO 20 I=1,IMAX
   20 X(I)=X(I)-XMEANX
C     PRINT 1002, (X(I),I=1,IMAX)
C1002 FORMAT (5E19.10)
      DO 30 J=1,JMAX
   30 SUMY=SUMY+Y(J)
      XJMAX=JMAX
      YMEANY=SUMY/XJMAX
      PRINT 1003, YMEANY
 1003 FORMAT(//10H YMEANY =          E20.10)
      DO 40 J=1,JMAX
   40 Y(J)=Y(J)-YMEANY
C     PRINT 1004, (Y(J),J=1,JMAX)
C1004 FORMAT(5E19.10)
      DO 50 I=1,IMAX
      DO 50 J=1,JMAX
   50 SUMZ=SUMZ+Z(I,J)
      XIJMAX=IMAX*JMAX
      ZMEANZ=SUMZ/XIJMAX
      PRINT 1005,ZMEANZ
 1005 FORMAT(//10H ZMEANZ =   E20.10)
      DO 60 I=1,IMAX
      DO 60 J=1,JMAX
   60 Z(I,J)=Z(I,J)-ZMEANZ
C EVALUATE ORTHOGONAL POLYNOMIALS
```

```
      XNUMA=0.
      DENA=0.
      DO 70 I=1,IMAX
      P(1,I)=1.
      XNUMA=XNUMA+U(I)*X(I)
   70 DENA=DENA+U(I)
C     PRINT 1007, DENA,XNUMA
C1007 FORMAT ( 7H DENA= 10X,F10.4, 8H XNUMA= 10X,F10.4)
      A(2)=XNUMA/DENA
      DO 80  I=1,IMAX
   80 P(2,I)=X(I)-A(2)
C     PRINT 1008,(P(2,I),I=1,IMAX)
 1008 FORMAT (9H P(2,I)= 10X,3F10.4)
      DO 90 N=3,NMAX
      XNUMA=0.
      DENA=0.
      DENB=0.
      DO 85 I=1,IMAX
      XNUMA=XNUMA+U(I)*X(I)*P(N-1,I)**2
      DENA=DENA+U(I)*P(N-1,I)**2
   85 DENB=DENB+U(I)*P(N-2,I)**2
C     PRINT 1085, XNUMA,DENA,DENB
C1085 FORMAT ( 8H XNUMA= F10.4, 7H DENA= F10.4,7H DENB= F10.4)
      A(N)=XNUMA/DENA
      B(N)=DENA/DENB
C     PRINT 1086, A(N),B(N)
C1086 FORMAT (    7H A(N)= F10.4, 7H B(N)= F10.4)
      DO 90 I=1,IMAX
   90 P(N,I)=(X(I)-A(N))*P(N-1,I)-B(N)*P(N-2,I)
C     PRINT 1090, (P(NMAX,I),I=1,IMAX)
C1090 FORMAT (12H P(NMAX,I)= 3F10.4)
      XNUMC=0.
      DENC=0.
      DO 100 J=1,JMAX
      Q(1,J)=1.
      XNUMC=XNUMC+W(J)*Y(J)
```

```
 100 DENC=DENC+W(J)
     C(2)=XNUMC/DENC
C    PRINT 1100, (Q(1,J),J=1,JMAX)
C1100 FORMAT (   9H Q(1,J)= 3F10.4)
C    PRINT 1101, XNUMC,DENC,C(2)
C1101 FORMAT (  8H XNUMC= F10.4,7H DENC= F10.4,7H C(2)= F10.4)
     DO 110 J=1,JMAX
 110 Q(2,J)=Y(J)-C(2)
C    PRINT 1102, (Q(2,J),J=1,JMAX)
C1102 FORMAT (   9H Q(2,J)= 3F10.4)
     DO 120 M=3,MMAX
     XNUMC=0.
     DENC=0.
     DEND=0.
     DO 115 J=1,JMAX
     XNUMC=XNUMC+W(J)*Y(J)*Q(M-1,J)**2
     DENC=DENC+W(J)*Q(M-1,J)**2
 115 DEND=DEND+W(J)*Q(M-2,J)**2
     C(M)=XNUMC/DENC
     D(M)=DENC/DEND
C    PRINT 1103, XNUMC,DENC,DEND,C(M),D(M)
C1103 FORMAT (8H XNUMC= F10.4,7H DENC= F10.4,7H DEND= F10.4, 7H C(M)=
C   1F10.4, 7H D(M)= F10.4)
     DO 120 J=1,JMAX
 120 Q(M,J)=(Y(J)-C(M))*Q(M-1,J)-D(M)*Q(M-2,J)
C    PRINT 1104,(Q(MMAX,J),J=1,JMAX)
C1104 FORMAT (12H Q(MMAX,J)= 3F10.4)
C EVALUATE CONTRIBUTION OF EACH ORTHOGONAL POLYNOMIAL TO THE MINIMIZA-
C TION OF THE RESIDUALS
     DO 130 N=1,NMAX
     DENPA(N)=0.
     DO 130 I=1,IMAX
 130 DENPA(N)=DENPA(N)+U(I)*P(N,I)**2
C    PRINT 1130,(DENPA(N),N=1,NMAX)
C1130 FORMAT  (11H DENPA(N)= 3F10.4)
     DO 140 M=1,MMAX
```

```
      DENQA(M)=0.
      DO 140 J=1,JMAX
  140 DENQA(M)=DENQA(M)+W(J)*Q(M,J)**2
C     PRINT 1140, (DENQA(M),M=1,MMAX)
C1140 FORMAT (11H DENQA(N)=        3F10.4)
      DO 160 N=1,NMAX
      DO 160 M=1,MMAX
      ALPH=0.
      DO 150 I=1,IMAX
      DO 150 J=1,JMAX
      ALPH=ALPH+U(I)*W(J)*Z(I,J)*P(N,I)*Q(M,J)
C     PRINT 1150,N,M,I,J,ALPH
  150 CONTINUE
C1150 FORMAT (3H N= I3,3H M= I3,3H I=I3,3H J=I3,6H ALPH=F10.4)
      ALPHA(N,M)=ALPH/(DENPA(N)*DENQA(M))
  160 BETA(N,M)=ALPHA(N,M)*ALPH
      DO 1160 N=1,3
C     PRINT 1161,(ALPHA(N,M),BETA(N,M),M=1,3)
C1161 FORMAT (22H ALPHA,BETA, ALTERNATE 6F10.4)
 1160 CONTINUE
C APPLICATION OF GAUSS CRITERION TO DETERMINE THE DEGREE POLY WHICH
C  YIELDS THE CLOSEST FIT TO THE GIVEN DATA
      SUMZSQ=0.
      DO 170 I=1,IMAX
      DO 170 J=1,JMAX
  170 SUMZSQ=SUMZSQ+U(I)*W(J)*Z(I,J)**2
C     PRINT 2170,SUMZSQ
C2170 FORMAT (10H  SUMZSQ = E20.10)
      IT=1
      IS=1
      DO 190 N=1,NMAX
      BETASUM=0.
      DO 190 M=1,MMAX
      XX=IMAX*JMAX-N*M
      DO 175 L=1,N
  175 BETASUM=BETASUM+BETA(L,M)
```

```
C     PRINT 1170,BETASUM
C1170 FORMAT ( 10H BETASUM= F10.4        )
      IF( BETASUM-SUMZSQ)   172,172,171
  171 TRIGAUS=0.
      GO TO 174
  172 IF (IMAX*JMAX-N*M) 2172,171,2172
 2172 TRIGAUS=(SUMZSQ-BETASUM)/XX
C 173 PRINT 1173,TRIGAUS
C1173 FORMAT ( 9HTRIGAUS= F10.4)
  174 IF(N-1) 176,375,176
  375 IF(M-1) 176,177,176
  177 GAUSCRT=TRIGAUS
C     PRINT 1177, GAUSCRT
C1177 FORMAT (  32H GAUSSCRIT EQUAL TRIALGAUSSCRIT F10.4)
      GO TO 190
  176 IF(GAUSCRT - TRIGAUS) 180,178,180
  178 IF(N*M-IS*IT) 179,180,180
  179 IS=N
      IT=M
  180 CONTINUE
C     PRINT 1180, GAUSCRT,TRIGAUS,N,M,IS,IT
 1180 FORMAT (  10H GAUSCRT= F10.4,10H TRIGAUS= F10.4,4I10)
      IF( GAUSCRT - TRIGAUS) 190,190,181
  181 GAUSCRT=TRIGAUS
      IS=N
      IT=M
  190 CONTINUE
      PRINT 1180,GAUSCRT,TRIGAUS, N,M,IS,IT
      NMAX=IS
      MMAX=IT
      TEMP=(IMAX*JMAX-NMAX*MMAX)/(IMAX*JMAX)
      XMINSQD=SQRTF( GAUSCRT*TEMP)
C EVALUATION OF ORTHO POLY COEFFICIENTS
      DO 200 N=1,NMAX
      PC(N,N)=1.
      NM1=N-1
```

```
      DO 200 IS=1,NM1
      PC(N,IS) = -A(N)* PC(NM1,IS)
      IF(IS-1) 197,198,197
  197 PC(N,IS)= PC(N,IS) +PC(N-1,IS-1)
  198 IF(IS-NM1)  199,200,199
  199 PC(N,IS)=PC(N,IS) - B(N)* PC(N-2,IS)
C 200 PRINT 1106,N,IS,PC(N,IS)
  200 CONTINUE
C1106 FORMAT (4H N= I3,5H IS, I3, 11H PC(N,IS)= E19.10)
      DO 210 M=1,MMAX
      QC(M,M)=1.
      MM1=M-1
      DO 210 IT=1,MM1
      QC(M,IT)= -C(M)* QC(MM1,IT)
      IF(IT-1)207,208,207
  207 QC(M,IT)= QC(M,IT)+ QC(MM1,IT-1)
  208 IF(IT-MM1) 209,210,209
  209 QC(M,IT)=QC(M,IT)-D(M)*QC(M-2,IT)
C 210 PRINT 1107,M,IT,Q(M,IT)
  210 CONTINUE
C1107 FORMAT (4H M=I3,5H IT= I3, 11H QC(M,IT), E19.10)
C EVALUATION OF APPROXIMATING ORTHO POLY COEFF
      DO 230 IS=1,NMAX
      DO 220 IT=1,MMAX
      PHI(IS,IT)=0.
      DO 220 N=IS,NMAX
      DO 220 M=IT,MMAX
  220 PHI(IS,IT)=PHI(IS,IT)+ALPHA(N,M)*PC(N,IS)*QC(M,IT)
C     PRINT 1230,(PHI(IS,IT),IT=1,MMAX)
C1230 FORMAT (13H PHI(IS,IT)= 3F10.4)
  230 CONTINUE
C EVALUATE OF DEPENDENT VARIABLES USING THE APPROXIMATING ORTHO POLY
      CMINSQD=0.
      CSUMDIF=0.
      CMAXDIF=0.
      DO 250 I=1,IMAX
```

```
      DO 250 J=1,JMAX
      ZCOMP(I,J)=0.
  240 IS=NMAX
  248 POLY=PHI(IS,MMAX)
  241 IT=MMAX-1
  249 POLY=POLY*Y(J)+PHI(IS,IT)
      IF(IT-1) 1999,247,242
  242 IT=IT-1
      GO TO 249
  247      ZCOMP(I,J)=ZCOMP(I,J)*X(I)+POLY
C     PRINT 1108,POLY,I,J,  ZCOMP(I,J)
C1108 FORMAT (     7H POLY= F10.4, 4H I= I3, 4H J= I3,10HZCOMP(I,J) F10.4
  243 IF(IS-1) 2000,245,244
  244 IS=IS-1
      GO TO 248
  245 RESCOMP=Z(I,J)-ZCOMP(I,J)
      ZCOMP(I,J)=ZCOMP(I,J)+ZMEANZ
      CMINSQD=CMINSQD+U(I)*W(J)*RESCOMP**2
      ABRESCP=ABSF(RESCOMP)
      IF(ABRESCP-CMAXDIF) 250,250,246
  246 CMAXDIF=ABRESCP
  250 CONTINUE
      PRINT 1251
 1251 FORMAT(     80H1  COMPUTED Z(I,J) AS EVALUATED BY APPROXIMATING OR
     1THOGONAL POLYNOMIAL                     ///)
      PRINT 2105,(J,J=1,JMAX)
      DO 260 I=1,IMAX
  260 PRINT 2107, I, (ZCOMP(I,J),J=1,JMAX)
      CMINSQD=SQRTF(CMINSQD/XIJMAX   )
      CSUMDIF=CSUMDIF/XIJMAX
      IF (KODE) 261,262,261
  261 PRINT 1271,ICON
 1271 FORMAT(A1,///55HCOEFFICIENTS OF APPROXIMATING ORTHOGONAL POLYNOMIA
     1L              //)
      PRINT 1272
 1272 FORMAT(     7H DEGREE 30X  14H DEGREE  OF  Y//      7H OF  X    )
```

```
      NMAXM1=NMAX-1                                                     00003540
      PRINT 1273,(J,J=0,NMAXM1        )                                 00003550
      PRINT 1273,(J,J=0,NMAXM1        )                                 00003550
 1273 FORMAT( 10X,5I20)                                                 00003560
      DO 300 I=1,MMAX                                                   00003570
      II=I-1                                                            00003580
      PRINT 270,II ,(PHI(I,J),J=1,NMAX)                                 00003590
  270 FORMAT(//I5,5X,5E20.10/(10X,5E20.10))                             00003600
  300 CONTINUE                                                          00003610
  262 PHI(1,1)=PHI(1,1)+ZMEANZ                                          00003620
      WRITE TAPE 2,XMEANX,YMEANY,NMAX,MMAX,PHI                          00003625
      DO 4001 I=1,IMAX                                                  00003630
      DO 4001 J=1,JMAX                                                  00003640
 4001 ZDIFF(I,J)=Z(I,J)-ZCOMP(I,J)+ZMEANZ                               00003650
      PRINT 4002                                                        00003660
 4002 FORMAT( 1H1 20X, 42H TABLE OF DIFFERENCES Z(I,J)- ZCOMP(I,J)  ///)00003670
      PRINT 2105,(J,J=1,JMAX)                                           00003680
      DO 4003 I=1,IMAX                                                  00003690
 4003 PRINT 2107,I,(ZDIFF(I,J),J=1,JMAX)                                00003700
C  TO EVALUATE  NEW  DEPENDENT VARIABLES USING THE APPROX. POLY         00003710
      IF(NEWCTL)  500,501,500                                           00003720
  500 READ 502,NEWX,NEWY                                                00003730
  502 FORMAT(2I5)                                                       00003740
      READ 503,(X(I),I=1,NEWX)                                          00003750
      READ 503,(Y(J),J=1,NEWY)                                          00003760
  503 FORMAT (4F20.0)                                                   00003770
      DO 550 I=1,NEWX                                                   00003780
      DO 550 J=1,NEWY                                                   00003790
      ZCOMP(I,J)=0.                                                     00003800
      IS=NMAX                                                           00003810
  548 POLY=PHI(IS,MMAX)                                                 00003820
      IT=MMAX-1                                                         00003830
  549 POLY=POLY*(Y(J)-YMEANY)+PHI(IS,IT)                                00003840
      IF(IT-1) 2000,547,542                                             00003850
  542 IT=IT-1                                                           00003860
      GO TO 549                                                         00003870
```

```
  547 ZCOMP(I,J)=ZCOMP(I,J)*(X(I)-XMEANX)+POLY
  543 IF(IS-1)2000,550,544
  544 IS=IS-1
      GO TO 548
  550 CONTINUE
C  PRINT NEW DEPENDENT VARIABLES
      IF(NEWX-8)  3101, 3101,3102
 3101 IF(NEWY-16) 3103, 3103, 3104
 3103 JCON =1H0
      GO TO 3110
 3104 JCON =1H1
      GO TO 3110
 3102 IF(NEWX-16) 3105,3105,3104
 3105 IF(NEWY-10) 3103,3103,3104
 3110 PRINT 551   ,JCON
  551 FORMAT(A1,///50H COMPUTED Z(I,J) EVALUATED FROM NEW X AND NEW Y
     1             ///)
      PRINT 2105,(J,J=1,NEWY)
      DO 560  I=1,NEWX
  560 PRINT 2107,I,(ZCOMP(I,J),J=1,NEWY)
  501 PHI(1,1)=PHI(1,1)-ZMEANZ
      CALL POLYXY(PHI,NMAX,MMAX,-XMEANX,-YMEANY)
      PHI(1,1)=PHI(1,1)+ZMEANZ
C     PRINT  SCALED COEFFICIENTS ARRAY
      PRINT 2108
 2108 FORMAT(     45H1  COEFFICIENTS OF APPROXIMATING POLYNOMIAL    /// )
      PRINT 1272
      PRINT 1273,(N,N=0,NMAXM1)
      DO 301 I=1,MMAX
      II=I-1
      PRINT 270,II ,(PHI(I,J),J=1,NMAX)
  301 CONTINUE
      PRINT 1190
 1190 FORMAT (////91H  MEAN SQUARED        COMPUTED MEAN SQUARED
     1MAXIMUM DIFFERENCES                                ///)
      PRINT 1270,XMINSQD,CMINSQD,CMAXDIF
```

```
1270 FORMAT (E15.10,5X,E20.10, 7X,E20.10///)
     RETURN
2000 PRINT 2001
2001 FORMAT (   6H ERROR)
     RETURN
1999 PRINT 1990
1990 FORMAT(15H IT ERROR STOP      )
     STOP
     END
```

```
      SUBROUTINE POLYXY(PHI,NMAX,MMAX,XMEANX,YMEANY)
      DIMENSION R(45),PHI(45,45),C(45)
      NM1=NMAX-1
      MM1=MMAX-1
      DO 40 I=1,NM1
   40 R(I)=-XMEANX
C     FIND COEFF ARRAY C OF POLY=(X-XMEANX)**I-1
      DO 10 I=2,NMAX
      CALL COEFFN(C,R,I-1)
C     PRINT 200,(C(M),M=1,I )
  200 FORMAT(  7H COEFF   5E20.10)
C NEED IMPROVMENT HERE AFTER PROGRAM CHECK OUT
      DO 10 J=1,MMAX
      K=I-1
   11 PHI(K,J)=PHI(K,J)+C(K)*PHI(I,J)
C     PRINT 201,I,J,K,PHI(K,J)
  201 FORMAT (3H I=I2,3H J=I2,3H K=I2,   E20.10)
      K=K-1
      IF(K)11,10,11
   10 CONTINUE
C     PRINT 20,((PHI(I,J),J=1,3),I=1,3)
   20 FORMAT(3F10.5)
      DO 140 I=1,MM1
  140 R(I)=-YMEANY
C     FIND COEFF ARRAY C FOR Y POLY=(Y-YMEANY)**I-1
      DO 110 J=2,MMAX
      CALL COEFFN(C,R,J-1)
C     PRINT 200,(C(M),M=1,J )
      DO 110 I=1,NMAX
      K=J-1
  111 PHI(I,K)=PHI(I,K)+C(K)*PHI(I,J)
C     PRINT 201,I,J,K,PHI(K,J)
      K=K-1
      IF(K)111,110,111
  110 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE COEFFN(A,R,N)
      DIMENSION CT(45),S(45),A(45),R(45),CL(45)
C      A(1)=COEFF OF CONSTANT,  A(2)=COEFF OF X,  ....A(N+1)=COEFF OF X*
      CT(1)=0.
      CL(1)=0.
      DO 10  I=1,N
      CT(I+1)=R(I)
      CL(I+1)=CT(I+1)
      S(I) = 0.
   10 S(1) = S(1)+R(I)
      A(1) = S(1)
      DO 20  I=2,N
   20 A(I) = A(I-1)-R(I-1)
      DO 40  J=2,N
      DO 35 I=J,N
      IM=I-1
      SUM=0.
      DO 31 K=1,IM
   31 SUM=SUM+CL(K)
   35 CT(I)=R(I-1)*SUM
      DO 30  I=J,N
   30 S(J)=S(J)+CL(I)*A(I)
      S(J)=S(J)*(-1.)**J
      DO 40 I=1,N
   40 CL(I)=CT(I)
      S(1)=(-1.)*S(1)
      DO 41 I=1,N
   41 A(I)=S(N+1-I)
      A(N+1)=1.
      RETURN
      END
```

APPENDIX III

BOTTOM TYPE CODING AND ITS APPLICATION

In examining the aspects of minelaying it becomes obvious that the events of importance should include mine burying and damage to the mine on bottom impact (the latter becomes of particular importance in aerial mining). It is also clear that the outcomes of these events are dependent on the type of bottom material at the mine's final position as well as water depth. It is assumed that for water depths greater than 20 feet the mine's sinking rate has greatly slowed and is a function of the mine's weight and dynamic drag only; hence in the aircraft and ship sequences of events the probability of damage on bottom impact is zero for water depths greater than 20 feet. In the submarine sequence, since there always exists some possibility of the mine retaining some additional velocity from tube ejection or self-propulsion, the probability of impact damage is always considered, but it is small and independent of water depth.

It is assumed that the type of bottom material can be represented by a numeric code for each of the bottom sediments in the order of their increasing consistency on a scale of zero to five as in Figure 17.

.0				1.0	2.0			3.0	4.0		5.0
OOZE	MUD	CLAY	MARL	SAND	GRAVEL	PEBBLES	SHINGLE	CORAL	STONES	ROCKY	BOULDERS

Figure 17. Scale for Bottom Material[4,5]

Further, an examination of any nautical chart demonstrates the variability of bottom material over the area of a typical minefield. To simulate the variability in bottom material a grid, preferably the same grid as used to code water depth, is superimposed over the area under consideration and each grid point is assigned a value according to the scale in Figure 17. A surface polynomial is then fitted to the bottom type values as described in Appendix II.

It is also assumed that the probability of burying and the probability of damage on bottom impact are linear functions of bottom type, i.e., the value assigned to the material at the mine's final position. The probability of burying has a maximum of the probability of burying in the softest bottom (PBSB) provided by the user for each mine type for ooze and a minimum of zero for boulders, and has the following equation:

[4] U.S. Navy Hydrographic Office, Nautical Chart Symbols and Abbreviations, Chart No. One, January, 1957, p.14.

[5] N. Bowditch, American Practical Navigator, U.S. Navy Hydrographic Office Publication No. Nine, 1958, p.108.

$$PB = PBSB - (PBSB / 5.0)(BTMTYP)$$

where PB is the probability of burying and BTMTYP is the value for the bottom material. The probability of bottom impact damage has a maximum of the probability of bottom impact damage on the hardest bottom (PDHB) provided by the user for each mine type for boulders and a minimum of zero for ooze, and has the following equation:

$$PD = (PDHB / 5.0)(BTMTYP)$$

where PD is the probability of damage on bottom impact. For example, let BTMTYP have the value, two, i.e., gravel. Assume the user has provided a value of .95 for PBSB and a value of .75 for PDHB, then

$$PB = .95 - (.95 / 5.0)(2.0) = .57$$

$$PD = (.75 / 5.0)(2.0) = .34 \quad .$$

A uniform random number is then compared to these probabilities to determine whether the mine buries or not and whether the mine is damaged or not.

APPENDIX IV

PROGRAM LISTING, INPUT FORMAT, AND VARIABLE NAMES

FOR PROGRAM MINDEL

On the succeeding pages of this appendix appear the program listing, input format, and variable names for Program MINDEL. The input format immediately follows the program listing and describes the punched card input data deck by card type. The card types are shown in the order of their appearance in the data deck along with an indication of the number of cards of each type required and their order. Further, for each card type, there is a sample FORTRAN card strip on which letters are punched according to the format required by the program. Below each card strip in four columns appear the letter keys corresponding to the letters on the card strip, the FORTRAN specifications, the variable names as they appear in the program, and brief definitions. Included in each definition and by notes where appropriate are guidelines to variable values and to the program changes required when certain values are exceeded. Following the input format section an alphabetical list of all variable names and their definitions which appear in Program MINDEL and except those defined in the input format is presented.

```
      PROGRAM MINDEL
      DIMENSION VAL(50,11),ACCL(10,6),ACLDL(8,31),ACMCL(24,14),XLDL(277)
     1,TD(135),BR(7,6),PHI(45,45),MDL(167,8),OUTPUT(30),XLCOD(6),SHCL(1
     20,9),SHLDL(7,70),SHMCL(10,8),BOT(45,45),SULDL(4,37),SUCL(10,17),SU
     3MCL(8,13),IRMAT(100),BRTEMP(7,6),PROB(14),SMROB(20),FXPTS(10),FYPT
     4S(10)
      COMMON PHI,VAL,ACLDL,SHLDL,SULDL,MDL,BOT,ACMCL,XLDL,SUCL,SHCL
      READ 10,NV,NA,NAT,MACT,NSH,NSHT,MSHT,NSU,NSUT,MSUT,MINTOT
      REWIND 2
      READ TAPE 2, NF,NACR,NACC,NSHR,NSHC,NSUR,NSUC,XREF,YREF,(FXPTS(I),
     1I=1,NF),(FYPTS(I),I=1,NF),((ACLDL(I,J),I=1,NACR),J=1,NACC),((SHLDL
     2(I,J),I=1,NSHR),J=1,NSHC),((SULDL(I,J),I=1,NSUR),J=1,NSUC)
      READ TAPE 2,XMEANX,YMEANY,NMAX,MMAX,PHI
      READ TAPE 2,XMEANX,YMEANY,NMAX1,MMAX1,BOT
C     NV=TOTAL NO. OF VEHICLES ON ARRIVAL LIST, NA=TOTAL NO. OF
C     AIRCRAFT,NAT=TOTAL NUMBER OF AIRCRAFT TYPES,NACR=NO. OF ROWS
C     IN ACLDL,NACC=NO. OF COLUMNS IN ACLDL,MACT=TOTAL NO. OF
C     AIRCRAFT MINE TYPES,NSH=TOTAL NO.OF SHIPS,NSHT=TOTAL NO. OF
C     SHIP TYPES,NSHR=NO. OF ROWS IN SHLDL,NSHC=NO. OF COLUMNS IN
C     SHLDL,MSHT=TOTAL NO. OF SHIP MINE TYPES,NSU=TOTAL NUMBER OF SUBMA-
C     RINES, NSUT=TOTAL NO. OF SUBMARINE TYPES,NSUR=NO. OF ROWS IN SULDL,
C     NSUC=NO. OF COLUMNS IN SULDL,MSUT=TOTAL NO. OF SUBMARINE MINE TYPES,
C     MINTOT=TOTAL NO. OF MINES.
   10 FORMAT(11I5)
      READ 1,((VAL(I,J),J=1,11),I=1,NV)
    1 FORMAT(F8.1,4F3.0,6F10.0)
      READ 2,((ACCL(I,J),J=1,6),I=1,NAT)
    2 FORMAT(4F5.0,2F4.2)
      READ 3,((ACMCL(I,J),J=1,14),I=1,MACT)
    3 FORMAT(F4.0,F6.2,2F6.0,5F6.2,2F3.0,3F6.2)
      READ 4,((BR(I,J),J=1,6),I=1,NA)
    4 FORMAT(6F10.0)
      READ 65,((MDL(I,J),J=1,8),I=1,MINTOT)
   65 FORMAT(4I5,I8,3I5)
      READ 303,((SHCL(I,J),J=1,9),I=1,NSHT)
  303 FORMAT (9F5.0)
      READ 302,((SHMCL(I,J),J=1,8),I=1,MSHT)
```

```
  302 FORMAT(8F5.0)
      READ 409,((SUCL(I,J),J=1,17),I=1,NSUT)
  409 FORMAT (F2.0,5F5.0,F3.2,F4.1,3F3.2,3F4.1,2F3.2,F10.0))
      READ 411,TAM
  411 FORMAT(F10.1)
      READ 430, ((SUMCL(I,J),J=1,13),I=1,MSUT)
  430 FORMAT(F5.0,2F5.2,F3.0,F5.0,6F5.2,F5.0,F5.2)
      READ 8001,IRMAT
 8001 FORMAT(8I10)
      READ 8002, NREP
 8002 FORMAT(I3)
      REWIND 3
      IF(TAM) 667,667,666
  667 DO 668 ISUB = 1,NV
      IF(VAL(ISUB,2)-9.)668,668,669
  669 TAM = VAL(ISUB,1)
      GO TO 666
  668 CONTINUE
  666 WRITE TAPE 3,XREF,YREF,FXPTS,FYPTS,ACLDL,SHLDL,SULDL,VAL,ACCL,SHCL
     1,SUCL,ACMCL,SHMCL,SUMCL,BR,MDL,NV,NA,NAT,NACR,NACC,MACT,NSH,NSHT,N
     2SHR,NSHC,MSHT,NSU,NSUT,NSUR,NSUC,MSUT,MINTOT,NF,TAM
      DO 8500 IREP=1,NREP
      IR = IRMAT(IREP)
      PRINT 8003,IREP
 8003 FORMAT(1H1,8H RUN NO.,I3//)
      PRINT 40
   40 FORMAT(//51X,19H  SUMMARY NARRATIVE///2X,5H TIME,10X,6H EVENT//)
C DUPLICATES BOMBRACK MATRIX FOR USE IN ITERATIVE RUNS.
      DO 8010 LL1=1,NV
```

```
      DO 8020 LL2=1,6
 8020 BRTEMP(LL1,LL2) = BR(LL1,LL2)
 8010 CONTINUE
      DO 8055 III =1,30
 8055 OUTPUT(III)=0.
      OUTPUT(28)=IR
      OUTPUT(29)=IREP
      WRITE TAPE 3,OUTPUT
C  SELECTION OF VEHICLES IN ORDER OF APPEARANCE ON VEHICLE ARRIVAL LIST
      DO9999 IABC=1,NV
      I=IABC
C  DETERMINATION AND INDEXING OF VEHICLE TYPE
      IF(VAL(I,2)-100.)305,102,102
  305 IF(VAL(I,2)-10.) 405,306,306
  405 J = VAL(I,2)
      S=SUCL(J,3)*2025.37/ 60.
      TD100=SUCL(J,17)/(SUCL(J,2)*2025.37/ 60.)
      MR=0
      BNE=SUCL(J,4)
      ANE=SUCL(J,5)
      GNE=SUCL(J,6)
      JJ = 3
      GO TO 103
  306 J=VAL(I,2)-9.
      S=SHCL(J,3)*2025.37/60.
      BNE=SHCL(J,4)
      ANE=SHCL(J,5)
      GNE=SHCL(J,6)
      JJ=2
      IDAM=0
      GO TO 103
  102 J = VAL(I,2) -99.
      S = ACCL(J,3) * 2025.37 / 60.
      JJ = 1
  103 MM = 2
      TD(1) = 0.
```

```
      NTOTLG = VAL(I,4)
      DO301 IL=1,6
      NIL = IL+ 5
  301 XLCOD(IL) = VAL(I,NIL)
      DO 104 KK = 1,NTOTLG
C DETERMINATION OF LEGS ASSIGNED VEHICLE AND TIME INCREMENTS IN FIELD
      CALL XTLEGN(XLCOD,L)
      GO TO(105,106,107),JJ
  105 N1 = 3.*ACLDL(L,2)+7.
C DETERMINES DELTA TIME BETWEEN LEGS IF MORE THAN ONE LEG ASSIGNED
      DO108 KKK = 1,N1
  108 XLDL(KKK) = ACLDL(L,KKK)
      N = ACLDL(L,2)+1.
      GO TO 308
  107 N = SULDL(L,2) + 1.
      DO 406 JIK = 1,4
  406 XLDL(JIK) = SULDL(L,JIK)
      DO 407 JI1 = 1,N
      NJ1=JI1 * 5-1
      NJ11 = NJ1 - (JI1 - 1)* 2
      DO 408 JI2= 1,3
      NJ2=NJ1 + JI2
      NJ22 = NJ11 + JI2
  408 XLDL(NJ22) = SULDL(L,NJ2)
  407 CONTINUE
      GO TO 308
  106 N1=3.*SHLDL(L,2)+7.
      DO 307 KKK=1,N1
  307 XLDL(KKK)=SHLDL(L,KKK)
      N=SHLDL(L,2)+1.
  308 IF(KK-1)109,109,110
  110 XIPX = XLDL(3)
      YIPY = XLDL(4)
      DX = (XIPX - TPX)**2
      DY = (YIPY - TPY)**2
      TE = (SQRTF(DX+DY))/S
```

```
      TD(MM) = TE + TD(MM-1)
      MM = MM + 1
C  DETERMINES DELTA TIME BETWEEN POINTS ON A LEG
  109 DO111 II = 1,N
      I1 = 3*(II-1)+6
      I2 = 3*(II-2)+6
      I3 = I1+1
      I4 = I2+1
      IF(II-1)112,112,113
  112 DX = (XLDL(6) - XLDL(3))**2
      DY = (XLDL(7) - XLDL(4))**2
      GO TO 114
  113 DX = (XLDL(I1)-XLDL(I2))**2
      DY = (XLDL(I3)-XLDL(I4))**2
  114 TE = (SQRTF(DX+DY))/S
      TD(MM) = TE + TD(MM-1)
      MM = MM + 1
      TPX = XLDL(I1)
  111 TPY = XLDL(I3)
  104 CONTINUE
   27 GO TO (28,310,415),JJ
C DETERMINE IF SUBMARINE IS DETECTED AND TIME OF DETECTION.
  415 PROB(1)=(1.0-SUCL(J,9))*(1.0- SUCL(J,11))
      PROB(2) = PROB(1) + (1.0-SUCL(J,9))*SUCL(J,11)*(1.0 - SUCL(J,12))
      PROB(3) = PROB(2) + (1.0-SUCL(J,9))*SUCL(J,11)* SUCL(J,12)*(1.
     10 - SUCL(J,13))
      PROB(4) = PROB(3) + (1.0-SUCL(J,9))* SUCL(J,11)*SUCL(J,12)* SU
     1CL(J,13)
      PROB(5) = PROB(4) + SUCL(J,9) * (1.0 - SUCL(J,10)) * (1.0 - SUCL(J
     1,15))
      PROB(6) = PROB(5) + SUCL(J,9) * (1.0- SUCL(J,10)) * SUCL(J,15)*
     1(1.0 - SUCL(J,16))* (1.0- SUCL(J,14))
      PROB(7) = PROB(6) + SUCL(J,9) * (1.0- SUCL(J,10)) * SUCL(J,15)*
     1(1.0- SUCL(J,16))*SUCL(J,14)
      PROB(8)= PROB(7) + SUCL (J,9) * (1.0-SUCL(J,10))* SUCL(J,15) *
     1SUCL(J,16)
```

```
      PROB(9) = PROB(8) + SUCL(J,9)* SUCL(J,10)*SUCL(J,12)*(1.0-S
     1UCL(J,13))
      PROB(10) = PROB(9) + SUCL(J,9) * SUCL(J,10) * SUCL(J,12) * SUCL(J
     1,13)
      PROB(11) = PROB(10) + SUCL(J,9) * SUCL(J,10) * (1.0- SUCL(J,12))
     1*(1.0- SUCL(J,15))
      PROB(12) = PROB(11) + SUCL(J,9) * SUCL(J,10)*(1.0- SUCL(J,12))
     1*SUCL(J,15)* SUCL(J,16)
      PROB (13) = PROB(12) +SUCL(J,9) *SUCL(J,10)*(1.0- SUCL(J,12))
     1* SUCL(J,15)*(1.0- SUCL(J,16))* (1.0-SUCL(J,14))
      PROB(14)=PROB(13) + SUCL(J,9)*SUCL(J,10)*(1.0-SUCL(J,12))
     1* SUCL(J,15)* (1.0- SUCL(J,16))* SUCL(J,14)
      CALL RAN1(IR,RN)
C PSEUDO DETECTION TIME,TYPE OF DETECTION AND/OR ATTRITION,IF ANY,DETERMINE
C DEVELOPMENT OF SUBMARINE NARRATIVE.
      DT= TD(MM-1)*RN
      TOTTIM = TD(MM-1)
      MQ = MM-1
      CALL TIMDIF(VAL(I,1),TAM,TDIF)
      GO TO 31
C DETERMINE IF SHIP SUFFERS DAMAGE AND TIME OF DAMAGE
  310 PU = SHCL(J,9)
      ALPHA = LOGF(PU+1.)/.7
      T = .5*(LOGF(2.)/LOGF(PU+1.))
      IF(T-TD(MM-1))311,311,312
  311 CALL RAN1(IR,RN)
      DT = TD(MM-1)*RN
C     PRINT 315,TD(MM-1),T,DT
      GO TO 31
  312 PDAM = EXPF(1.4*ALPHA*TD(MM-1))-1.
      CALL RAN1(IR,RN)
      IF(PDAM-RN)313,311,311
C SET DUMMY DAMAGE TIME GREATER THAN TOTAL TIME IN FIELD
  313 DT = TD(MM-1) + 60.
C     PRINT 315,TD(MM-1),T,DT
C 315 FORMAT(27H DAMAGE TEST. TOTAL TIME = ,F10.1, 5H T = ,F5.1, 6H DT =
```

```
C     1 ,F10.1/)                                                         02150
        GO TO 31                                                         02160
C   DETERMINE IF AIRCRAFT SURVIVES                                       02180
    28 CALL RAN1(IR,RN)                                                  02190
        IF(RN-ACCL(J,6))29,29,30                                         02200
C   SET DUMMY DEAD TIME GREATER THAN TOTAL TIME IN FIELD                 02210
    29 DT = TD(MM-1)+5.                                                  02220
C       PRINT 32,VAL(I,3),DT                                             02230
C   32 FORMAT(8H A/C NO.,F4.0,29H SURVIVES. DUMMY DEAD TIME = ,F5.1//)   02240
        GO TO 31                                                         02250
C   DETERMINE DEAD TIME                                                  02260
    30 CALL RAN1(IR,RN)                                                  02270
        DT = TD(MM-1)*RN                                                 02280
C       PRINT 33,VAL(I,3),DT                                             02290
C   33 FORMAT(8H A/C NO.,F4.0,19H DIES. DEAD TIME = ,F5.1//)             02300
    31 MM = 2                                                            02310
        DO480 IL=1,6                                                     02320
        NIL = IL+ 5                                                      02330
   480 XLCOD(IL) = VAL(I,NIL)                                            02340
        GO TO(316,317,420),JJ                                            02350
C   BEGIN DEVELOPEMENT OF SUBMARINE NARRATIVE                            02360
   420 CALL XTLEGN(XLCOD,L)                                              02370
        DO 500 K=1,NTOTLG                                                02380
        NMINES = SULDL(4,2)+1.                                           02390
        DO 501 NMIN = 1, NMINES                                          02400
        DO 502 III=1,30                                                  02410
   502 OUTPUT(III) = 0.                                                  02420
        IF(K-1)503,503,504                                               02430
   503 IF(NMIN-1)505,505,504                                             02440
   505 PRINT 506,VAL(I,1),VAL(I,3),L                                     02450
   506 FORMAT(F10.1,14H SUBMARINE NO.,F4.0,26H ARRIVES AT IP FOR LEG NO.,  02460
      1I4 /)                                                             02470
        GO TO 507                                                        02480
   504 IF(NMIN - NMINES)507,508,508                                      02490
C SUBMARINE MINE FIRING DELAY ROUTINE.                                   02500
   507 SDELAY = 0.                                                       02510
```

```
      LDFLAG=1
      TREF=TD(MM)
      NM = 5*(NMIN-1)+5
      M1 = SULDL(L,NM)
  513 CALL RAN1(IR,RN)
      IF(SUCL(J,7)-RN)510,509,509
  510 CALL RAN1(IR,DELAY)
      SDELAY = SDELAY + DELAY
      IF(SDELAY-SUCL(J,8))511,511,512
  511 TREF = SDELAY + TD(MM)
      IF(TREF - TD(MM+1))513,512,512
C STORE MINES NOT FIRED DUE TO EXCESSIVE FIRING DELAY.
  512 MR = MR+1
      SMROB(MR)=M1
      CALL TIMCON(VAL(I,1),TREF,TLAY)
      PRINT 514,TLAY,SULDL(L,NM)
  514 FORMAT(F10.1,9H MINE NO.,F4.0,38H NOT LAYED DUE TO EXCESSIVE TIME
     1DELAY /)
      MLFLAG = 0
      GO TO 520
  509 IF(TREF-DT)516,515,515
C DETERMINE TYPE OF EVASIVE ACTION/DETECTION/ATTRITION EVENT.
  515 CALL RAN1(IR,RN)
      DO 517 JCIG = 1,14
      IDET = JCIG
      IF(PROB(JCIG)-RN)517,518,518
  517 CONTINUE
  518 CALL TIMCON(VAL(I,1),DT,TDT)
      GO TO (539,539,521,522,523,524,525,526,527,528,529,530,531,532),ID
     1ET
  539 DT = 2.0*TOTTIM
      GO TO 516
  521 PRINT 533,TDT,VAL(I,3)
      IDET1=1
      GO TO 550
  522 PRINT 533,TDT,VAL(I,3)
```

```
533 FORMAT(F10.1,8H SUB NO.,F4.0,54H SUSPENDS OPS DUE TO ERRONEOUS KNO
   1WLDEGE OF DETECTION. /)
    IDET1=1
    GO TO 560
523 PRINT 534,TDT,VAL(I,3)
534 FORMAT(F10.1,8H SUB NO.,F4.0,10H DETECTED. /)
    GO TO 516
524 PRINT 535,TDT,VAL(I,3)
535 FORMAT(F10.1,8H SUB NO.,F4.0,23H DETECTED AND ATTACKED. /)
    IDET1=1
    GO TO 550
525 PRINT 535,TDT,VAL(I,3)
    IDET1=2
    GO TO 560
526 PRINT 535,TDT,VAL(I,3)
    IDET1=2
    GO TO 550
527 PRINT 536,TDT,VAL(I,3)
536 FORMAT(F10.1,8H SUB NO.,F4.0,27H DETECTED AND SUSPENDS OPS. /)
    IDET1=1
    GO TO 550
528 PRINT 536,TDT,VAL(I,3)
    IDET1=1
    GO TO 560
529 PRINT 534,TDT,VAL(I,3)
    GO TO 516
530 PRINT 535,TDT,VAL(I,3)
    IDET1=2
    GO TO 550
531 PRINT 535,TDT,VAL(I,3)
    IDET1=1
    GO TO 550
532 PRINT 535,TDT,VAL(I,3)
    IDET1=2
560 GO TO(540,544),IDET1
540 CALL RAN1(IR,RN)
```

```
      TRET=DT+2.*TD100+(TDIF-DT)*RN
  545 CALL TIMCON(VAL(I,1),TRET,TTRET)
      IDET1=3
      IF(TAM - TTRET)550,550,541
  541 GO TO(537,591,591),LDFLAG
  591 IF(K - NTOTLG) 537,592,592
  592 PRINT 593
  593 FORMAT(22X,32H MISSION COMPLETED. LEAVES AREA. //)
      GO TO 9999
  537 PRINT 542,TTRET,VAL(I,3)
  542 FORMAT(F10.1,8H SUB NO.,F4.0,13H RESUMES OPS. /)
  594 DO 543 JUP =MM,134
  543 TD(JUP+1) = TRET + (TD(JUP+1)-TD(MM))+10.*RN
      TOTTIM = TD(MQ)
      TREM = TOTTIM -TD(MM)
      TD(MM) = TRET +10.*RN
      CALL RAN1(IR,RN)
      DT = TRET + TREM*RN
      GO TO(597,595,589),LDFLAG
  595 MM = MM + 1
      GO TO 589
  544 CALL RAN1(IR,RN)
      TRET = DT + 2.*TD100 +2.*(TDIF-DT)*RN
      GO TO 545
  550 GO TO(546,547,548),IDET1
  546 PRINT 549
  549 FORMAT(22X,45H ABORTS MISSION. MINES REMAINING ON BOARD ARE )
      GO TO 561
  547 PRINT 551
  551 FORMAT(22X,40H ATTRITTED. MINES REMAINING ON BOARD ARE )
      GO TO 561
  548 TQ = TDIF - TD100
      CALL TIMCON(VAL(I,1),TQ,TDT)
      PRINT 552,TDT,VAL(I,3)
  552 FORMAT(F10.1,8H SUB NO.,F4.0,68H ABORTS MISSION DUE TO TIME LIMITA
     1TION. MINES REMAINING ON BOARD ARE )
```

```
  561 DO 556 IDOT = 1,NR
      PRINT 538,SMROB(IDOT)
  556 CONTINUE
  553 DO 554 NLEGR = K,NTOTLG
      NMINES =-SULDL(L,2)
      DO 555 NMINR = NMIN,NMINES
      NM = 5*(NMINR-1)+5
      PRINT 538,SULDL(L,NM)
  538 FORMAT(90X,F4.0)
  555 CONTINUE
      NMIN=1
      CALL XTLEGN(XLCOD,L)
  554 CONTINUE
      GO TO 9999
C DETERMINE SUBMARINE FIRING POSITION.
  516 GO TO(519,585,589),LDFLAG
  519 IF(TREF-TDIF)563,562,562
  562 PRINT 552,TAM,VAL(I,3)
      GO TO 561
  563 MLFLAG = 1
      XDELE = 0.
      YDELE = 0.
      CALL POSIT(IR,BNE,ANE,GNE,SULDL(L,NM+1),SULDL(L,NM+2),XDELE,YDELE,
     1XPOSIT,YPOSIT)
      CALL TIMCON(VAL(I,1),TREF,TLAY)
      PRINT 265,TLAY,SULDL(L,NM)
      MT2=MDL(M1,2)
      MFLAG=SUMCL(MT2,4)
C DETERMINE IF MINE IS SELF-PROPELLED AND TERMINAL POSIT OF SELF-PROPELLED
      IF(SUMCL(MT2,8))576,576,567
  567 CALL RAN1(IR,RN)
      IF(SUMCL(MT2,8)-RN)569,570,570
  569 DX=XPOSIT-SULDL(L,NM+3)
      DY=YPOSIT-SULDL(L,NM+4)
      HYP=SQRTF(DX**2+DY**2)
      CALL RAN1(IR,RN)
      RUN=HYP*RN
```

```
C DETERMINE IF RUN IS NORMAL FOR SELF-PROPELLED MINE. IF NOT, DETERMINE TYP
C FAILURE AND CORRESPONDING MINE POSIT.
      CALL RAN1(IR,RN)
      IF(SUMCL(MT2,9)-RN)571,572,572
  571 IF(SUMCL(MT2,10)-RN)573,574,574
  572 XPOSIT=XPOSIT+RUN*DX/HYP
      YPOSIT=YPOSIT+RUN*DY/HYP
      OUTPUT(13)=1.
      IF(RUN-500.)575,575,576
  575 OUTPUT(12)=1.
      GO TO 576
  573 CALL RAN1(IR,RN)
      OUTPUT(15)=1.
      DRUN=(HYP-RUN)*RN+RUN
      XPOSIT=XPOSIT+DRUN*DX/HYP
      YPOSIT=YPOSIT+DRUN*DY/HYP
      GO TO 576
  574 OUTPUT(14)=1.
      CALL RAN1(IR,RN)
      GYRUN=(HYP-RUN)*RN
      CALL RAN1(IR,RN)
      GYPHI=6.28318*RN
      XPOSIT=XPOSIT+RUN*DX/HYP+GYRUN*COSF(GYPHI)
      YPOSIT=YPOSIT+RUN*DY/HYP+GYRUN*SINF(GYPHI)
      GO TO 576
  570 SIGMA=SUMCL(MT2,12)/1.1744
      CALL RNORM(SIGMA,XE,IR)
      CALL RNORM(SIGMA,YE,IR)
      XPOSIT=SULDL(L,NM+3)+XE
      YPOSIT=SULDL(L,NM+4)+YE
  576 CALL DEPTH(XPOSIT,YPOSIT,PHI,NMAX,MMAX,YMEANY,XMEANX,WD)
      IF(WD)577,577,578
  577 OUTPUT(9)=1.
      CALL TAPO(OUTPUT,TLAY,MT2,MDL(M1,3),MDL(M1,8),MDL(M1,7),MDL(M1,5),
     1MDL(M1,6),M1,XPOSIT,YPOSIT,WD,MFLAG)
      GO TO 520
```

```
578 CALL TAPO(OUTPUT,TLAY,MT2,MDL(M1,3),MDL(M1,8),MDL(M1,7),MDL(M1,5),
   1MDL(M1,6),M1,XPOSIT,YPOSIT,WD,MFLAG)
    CALL DEPTH(XPOSIT,YPOSIT,BOT,NMAX1,MMAX1,YMEANY,XMEANX,BTMTYP)
    CALL RAN1(IR,RN)
    PD=(SUMCL(MT2,2)/5.)*BTMTYP
    IF(PD-RN)579,580,580
580 OUTPUT(3)=1.
579 GO TO (581,581,582,582,581,581),MFLAG
581 CALL MOOR(OUTPUT,IR,MFLAG,WD,MDL(M1,4),SUMCL(MT2,6),SUMCL(MT2,7),S
   1UMCL(MT2,13))
    GO TO 520
582 CALL BOTTOM(OUTPUT,IR,MFLAG,BTMTYP,SUMCL(MT2,3),SUMCL(MT2,5),SUMCL
   1(MT2,13))
520 MM=MM+1
    IF(MLFLAG)501,501,583
583 WRITE TAPE 3, OUTPUT
501 CONTINUE
508 IF(DT-TD(MM))584,584,585
584 LDFLAG=2
    GO TO 515
585 CALL TIMCON(VAL(I,1),TD(MM),TTP)
    IF(TTP-TAM)599,596,596
599 MM=MM+1
    PRINT 586,TTP,VAL(I,3),L
586 FORMAT(F10.1,8H SUB NO.,F4.0,26H ARRIVES AT TP FOR LEG NO.,I4 //)
    IF(K - NTOTLG) 587,9999,9999
C DETERMINE IF SUBMARINE SURVIVES BETWEEN TP AND IP FOR NEXT LEG.
587 IF(DT-TD(MM))588,588,589
588 LDFLAG=3
    GO TO 515
589 CALL TIMCON(VAL(I,1),TD(MM),TIP)
    IF(TIP-TAM)597,596,596
596 PRINT 552,TAM,VAL(I,3)
    GO TO 561
597 MM=MM+1
    CALL XTLEGN(XLCOD,L)
```

```
      PRINT 598,TIP,VAL(I,3),L
  598 FORMAT(F10.1,8H SUB NO.,F4.0,26H ARRIVES AT IP FOR LEG NO.,I4/)
  500 CONTINUE
      GO TO 9999
C BEGIN DEVELOPEMENT OF SHIP NARRATIVE
  317 CALL XTLEGN(XLCOD,L)
      DO 318 K = 1,NTOTLG
      NMINES = SHLDL(L,2)+1.
      DO319 NMIN = 1,NMINES
      DO 320  III=1,30
  320 OUTPUT(III)=0.
      IF(K-1)321,321,322
  321 IF(NMIN-1)323,323,322
  323 PRINT 324,VAL(I,1),VAL(I,3),L
  324 FORMAT(F10.1, 9H SHIP NO.,F4.0,26H ARRIVES AT IP FOR LEG NO.,I4/)
      GO TO 325
  322 IF(NMIN-NMINES)325,452,452
C DETERMINE IF MINE RELEASES ON FIRST ATTEMPT
  325 CALL RAN1(IR,RN)
      IF(SHCL(J,7)-RN)326,327,327
  327 DELAY = 0.
      GO TO 328
  326 CALL RAN1(IR,RN)
      DELAY = SHCL(J,8)*RN
  328 TDUM = TD(MM)+DELAY
      IF(IDAM)329,329,347
  329 LDFLAG = 1
      IF(TDUM-DT)347,331,331
  331 IDAM=1
      CALL TIMCON(VAL(I,1),DT,TDT)
C DETERMINE IF SHIP IS DAMAGED AND TYPE OF DAMAGE.
      CALL RAN1(IR,RN)
      NDAM = RN*10.+1.
      GO TO(340,340,341,341,342,342,343,343,344,344,344),NDAM
  340 PRINT 345,TDT,VAL(I,3)
  345 FORMAT(F10.1, 9H SHIP NO.,F4.0,37H DAMAGED. SPEED REDUCED BY ONE-H
     1ALF. /)
```

```
      TREF2 = TD(MM)
      TREF1=(TD(MM)-DT)*2.+DT
      DO 346 JU = MM,134
  346 TD(JU+1)=(TD(JU+1)-TREF2)*2.+TREF1
      TDUM=TREF1 + DELAY
      S = S/2.
      GO TO(347,460,470),LDFLAG
  341 PRINT 348,TDT,VAL(I,3)
  348 FORMAT(F10.1,9H SHIP NO.,F4.0,37H DAMAGED. NAVIGATIONAL ERROR DOUB
     1LED./)
      BNE = BNE*2.
      ANE=ANE*2.
      GNE=GNE*2.
      GO TO(347,460,470),LDFLAG
  342 PRINT 349,TDT,VAL(I,3)
  349 FORMAT(F10.1,9H SHIP NO.,F4.0,31H DAMAGED. NO EFFECT ON MISSION./)
      GO TO(347,460,470),LDFLAG
  343 PRINT 350,TDT,VAL(I,3)
  350 FORMAT(F10.1,9H SHIP NO.,F4.0,35H SUNK. MINES REMAINING ON BOARD A
     1RE )
      GO TO 351
  344 PRINT 352,TDT,VAL(I,3)
  352 FORMAT(F10.1,9H SHIP NO.,F4.0,54H DAMAGED. ABORTS MISSION. MINES R
     1EMAINING ON BOARD ARE )
  351 DO 353 NLEGR = K,NTOTLG
      NMINES = SHLDL(L,2)
      DO354 NMINR = NMIN,NMINES
      NM = 3*(NMINR-1)+5
      PRINT 355,SHLDL(L,NM)
  355 FORMAT(77X,F4.0)
  354 CONTINUE
      NMIN = 1
      CALL XTLEGN(XLCOD,L)
  353 CONTINUE
      GO TO 9999
  347 NM = 3*(NMIN-1)+5
```

```
      M1 = SHLDL(L,NM)
      CALL TIMCON(VAL(I,1),TDUM,TLAY)
      PRINT 265,TLAY,SHLDL(L,NM)
      MT2 = MDL(M1,2)
      IF(DELAY)357,357,356
C DETERMINE SHIP DELIVERED MINE POSIT.
  356 DX = SHLDL(L,NM+4)-SHLDL(L,NM+1)
      DY = SHLDL(L,NM+5)-SHLDL(L,NM+2)
      HYP = SQRTF(DX**2 + DY**2)
      XDELE = DELAY*S*(DX/HYP)
      YDELE = DELAY*S*(DY/HYP)
C     PRINT 2001,XDELE,YDELE
      GO TO 358
  357 YDELE = 0.
      XDELE = 0.
C     PRINT 2001,XDELE,YDELE
C2001 FORMAT(/9H XDELE = ,F10.3,9H YDELE = ,F10.3 /)
  358 CALL POSIT(IR,BNE,ANE,GNE,SHLDL(L,NM+1),SHLDL(L,NM+2),XDELE,YDELE,
     1XPOSIT,YPOSIT)
      CALL DEPTH(XPOSIT,YPOSIT,PHI,NMAX,MMAX,YMEANY,XMEANX,WD)
C     PRINT 2003,WD
C2003 FORMAT(/6H WD = ,F10.3 /)
      CALL DEPTH(XPOSIT,YPOSIT,BOT,NMAX1,MMAX1,YMEANY,XMEANX,BTMTYP)
C     PRINT 2004,BTMTYP
C2004 FORMAT(/10H BTMTYP = ,F10.3 /)
      MFLAG = SHMCL(MT2,4)
      CALL TAPO(OUTPUT,TLAY,MT2,MDL(M1,3),MDL(M1,8),MDL(M1,7),MDL(M1,5),
     1MDL(M1,6),M1,XPOSIT,YPOSIT,WD,MFLAG)
      IF(WD-20.)362,362,363
  362 CALL RAN1(IR,RN)
      PDHB = SHMCL(MT2,2)
      PD=(PDHB/5.)*BTMTYP
      IF(PD-RN)363,364,364
  364 OUTPUT(3)=1.
  363 GO TO(365,365,367,367,365,365),MFLAG
  365 CALL MOOR(OUTPUT,IR,MFLAG,WD,MDL(M1,4),SHMCL(MT2,6),SHMCL(MT2,7),
```

```
   1SHMCL(MT2,8))
     GO TO 442
  367 CALL BOTTOM (OUTPUT,IR,MFLAG,BTMTYP,SHMCL(MT2,3),SHMCL(MT2,5),SHMC
     1L(MT2,8))
  442 MM=MM+1
      WRITE TAPE 3,OUTPUT
  319 CONTINUE
C DETERMINE IF SHIP SURVIVES TRANSIT FROM TP TO IP FOR NEXT LEG
  452 IF(IDAM)453,453,460
  453 IF(DT-TD(MM))455,455,460
  455 LDFLAG=2
      DELAY=0.
      GO TO 331
  460 CALL TIMCON(VAL(I,1),TD(MM),TTP)
      MM=MM+1
      PRINT 461,TTP,VAL(I,3),L
  461 FORMAT(F10.1,9H SHIP NO.,F4.0,26H ARRIVES AT TP FOR LEG NO.,I4 //)
      IF(K - NTOTLG) 462,9999,9999
  462 IF(IDAM)463,463,470
  463 IF(DT-TD(MM))464,464,470
  464 LDFLAG=3
      DELAY=0.
      GO TO 331
  470 CALL TIMCON(VAL(I,1),TD(MM),TIP)
      MM =  MM + 1
      CALL XTLEGN(XLCOD,L)
      PRINT 324,TIP,VAL(I,3),L
  318 CONTINUE
      GO TO 9999
C BEGIN DEVELOPMENT OF AIRCRAFT NARRATIVE
  316 CALL XTLEGN(XLCOD,L)
      DO 34 K=1,NTOTLG
      NMINES = ACLDL(L,2)+1.
      DO267 NMIN = 1,NMINES
      DO 266  III=1,30
  266 OUTPUT(III)=0.
```

```
      IF(K-1)36,36,37
   36 IF(NMIN-1)38,38,37
   38 PRINT 39,VAL(I,1),VAL(I,3),L
   39 FORMAT(F10.1,8H A/C NO.,F4.0,26H ARRIVES AT IP FOR LEG NO.,I4/)
      GO TO 41
   37 IF(NMIN-NMINES)41,42,42
   41 IF(DT-TD(MM))43,43,44
   44 CALL TIMCON(VAL(I,1),TD(MM),TLAY)
      NM = 3*(NMIN-1)+5
      NUBRS = VAL(I,5)
      NVEH = VAL(I,3)
C  SEARCH A/C BOMBRACKS FOR MINE THAT IS TO BE RELEASED
      DO 56 NUBR = 1,NUBRS
      CALL XTRACT(BRTEMP(NVEH,NUBR),XTRACL,XTRACX,XTRACR)
      IF(XTRACR-ACLDL(L,NM))56,57,56
   56 CONTINUE
      PRINT 58,TLAY,ACLDL(L,NM)
   58 FORMAT(F10.1,9H MINE NO.,F4.0,36H IS BLOCKED BY PRIOR RELEASE FAIL
     1URE/)
      MLFLAG = 0
      GO TO 35
   57 CALL RAN1(IR,RN)
C  DETERMINES IF MINE RELEASES
      IF(RN-ACCL(J,5))59,59,60
C  IF MINE RELEASES,BOMBRACK ARRAY IS MODIFIED
   59 BRTEMP(NVEH,NUBR)=XTRACL
C     PRINT 61,BRTEMP(NVEH,NUBR)
C  61 FORMAT(//30H BOMBRACK LOAD AFTER RELEASE = ,F19.0)
      PRINT 265,TLAY,ACLDL(L,NM)
  265 FORMAT(F10.1,9H MINE NO.,F4.0,7H LAYED /)
      MLFLAG =1
      GO TO 62
C  IF MINE DOES NOT RELEASE, BOMBRACK ARRAY IS NOT CHANGED
   60 PRINT 63,TLAY,ACLDL(L,NM)
   63 FORMAT(F10.1,9H MINE NO.,F4.0,16H DID NOT RELEASE/)
      MLFLAG =0
```

```
      GO TO 35
   62 M1 = ACLDL(L,NM)
      MT2 = MDL(M1,2)
      CALL RAN1(IR,RN)
      IF(ACMCL(MT2,2)-RN)70,69,69
   69 ECCENT = SQRTF((1.0-(ACMCL(MT2,3)-1.0)**2-1000.0**2)/(1.0-(ACMCL(M
     1T2,3)-1.0)**2))
      CEP = (SQRTF(1.0-((ACCL(J,4))**2)/(1.0-ECCENT**2))+1.0)/3.0
      SIGMA = CEP/1.1744
C     PRINT 71,ECCENT,CEP,SIGMA
C  71 FORMAT(//10H ECCENT = ,F20.10,5X,7H CEP = ,F20.10,5X,9H SIGMA = ,F
C    120.10//)
      CALL RAN1(IR,RN)
      IF(ACMCL(MT2,5)-RN)72,72,73
   73 OUTPUT(2)=1.
      GO TO 72
   70 OUTPUT(1)=1.
      ECCENT = SQRTF((1.0-(ACMCL(MT2,4)-1.0)**2-1000.0**2)/(1.0-(ACMCL(M
     1T2,4)-1.0)**2))
      CEP = (SQRTF(1.0-((ACCL(J,4))**2)/(1.0-ECCENT**2))+1.0)/3.0
      SIGMA = CEP/1.1744
C     PRINT 71,ECCENT,CEP,SIGMA
      CALL RAN1(IR,RN)
      IF(ACMCL(MT2,6)-RN)72,72,75
   75 OUTPUT(2)=1.
C COMPUTATION OF XPOSIT AND YPOSIT
   72 CALL RNORM(SIGMA,XE,IR)
      CALL RNORM(SIGMA,YE,IR)
      XPOSIT = ACLDL(L,NM+1) + XE
      YPOSIT = ACLDL(L,NM+2) + YE
      MFLAG = ACMCL(MT2,10)
C     PRINT 74,XE,YE,XPOSIT,YPOSIT
C  74 FORMAT(//6H XE = ,F10.4,6H YE = ,F10.4,10H XPOSIT = ,F10.4,10H YPO
C    1SIT = ,F10.4//)
      CALL DEPTH (XPOSIT,YPOSIT,PHI,NMAX,MMAX,YMEANY,XMEANX,WD)
      IF(WD)139,139,138
```

```
 139 OUTPUT(9) = 1.
     CALL TAPO(OUTPUT,TLAY,MT2,MDL(M1,3),MDL(M1,8),MDL(M1,7),MDL(M1,5),
    1MDL(M1,6),M1,XPOSIT,YPOSIT,WD,MFLAG)
     GO TO 35
 138 CALL TAPO(OUTPUT,TLAY,MT2,MDL(M1,3),MDL(M1,8),MDL(M1,7),MDL(M1,5),
    1MDL(M1,6),M1,XPOSIT,YPOSIT,WD,MFLAG)
C    PRINT 76,WD
C 76 FORMAT(/15H WATER DEPTH = ,E20.10,5H FEET /)
C INSERT TIDE ROUTINE HERE IF USED
     CALL DEPTH(XPOSIT,YPOSIT,BOT,NMAX1,MMAX1,YMEANY,XMEANX,BTMTYP)
     GO TO(85,85,86,86,85,85),MFLAG
  85 IF(WD-20.0)87,87,88
  87 IF(OUTPUT(1))89,89,90
  89 PDHB = ACMCL(MT2,7)
     GO TO 91
  90 PDHB = ACMCL(MT2,8)
  91 PD = (PDHB/5.)*BTMTYP
     CALL RAN1(IR,RN)
     IF(PD-RN)88,92,92
  92 OUTPUT(3)=1.
  88 CALL MOOR( OUTPUT,IR,MFLAG,WD,MDL(M1,4),ACMCL(MT2,12),ACMCL(MT2,13
    1),ACMCL(MT2,14))
     GO TO 35
C STATEMENT 86 BEGINS BOTTOM MINE LOOP.
  86 PB = ACMCL(MT2,9)
     IF(WD-20.)194,194,195
 194 IF(OUTPUT(1))196,196,197
 196 PB = PB + .1
     PDHB = ACMCL(MT2,7)
     GO TO 198
 197 PB = PB + .2
     PDHB = ACMCL(MT2,8)
 198 PD = (PDHB/ 5.)*BTMTYP
     CALL RAN1(IR,RN)
     IF(PD-RN)200,200,195
 200 OUTPUT(3)=1.
```

```
195 CALL BOTTOM (OUTPUT,IR,MFLAG,BTMTYP,PB,ACMCL(MT2,11),ACMCL(MT2,14)
   1)
 35 MM = MM + 1
    IF(MLFLAG)267,267,268
268 WRITE TAPE 3,OUTPUT
267 CONTINUE
 43 CALL TIMCON(VAL(I,1),DT,TDT)
    PRINT 46,TDT,VAL(I,3)
 46 FORMAT(F10.1,8H A/C NO.,F3.0,40H ATTRITED. MINES REMAINING ON BOAR
   1D ARE  )
 47 NVEH = VAL(I,3)
    NBR = VAL(I,5)
    DO 48 KK = 1,NBR
 50 CALL XTRACT(BRTEMP(NVEH,KK),XTRACL,XTRACX,XTRACR)
    PRINT 49,XTRACR
 49 FORMAT(58X,F4.0)
    BRTEMP(NVEH,KK)=XTRACL
    IF(XTRACL)48,48,50
 48 CONTINUE
    GO TO 9999
C  DETERMINE IF A/C SURVIVES TRANSIT FROM TP TO IP FOR NEXT LEG
 42 IF(DT-TD(MM))51,51,52
 51 CALL TIMCON(VAL(I,1),DT,TDT)
    PRINT 46,TDT,VAL(I,3)
    GO TO 47
 52 CALL TIMCON(VAL(I,1),TD(MM),TTP)
    MM = MM + 1
    PRINT 53,TTP,VAL(I,3),L
 53 FORMAT(F10.1,8H A/C NO.,F4.0,26H ARRIVES AT TP FOR LEG NO.,I4//)
    IF(K - NTOTLG) 54,9999,9999
 54 IF(DT-TD(MM))51,55,55
 55 CALL TIMCON (VAL(I,1),TD(MM),TIP)
    MM = MM + 1
    CALL XTLEGN(XLCOD,L)
    PRINT 39,TIP,VAL(I,3),L
 34 CONTINUE
```

```
9999 CONTINUE
8500 CONTINUE
     END FILE 3
     END
```

```
      SUBROUTINE XTLEGN(XLCOD,LEGNUM)
      DIMENSION XLCOD(6)
      IF(XLCOD(1)) 1,1,3
    1 DO 2 I=1,5
    2 XLCOD(I) = XLCOD(I + 1)
      XLCOD(6) = 000000000.0
    3 LEGNUM = XLCOD(1) / 1000000.0
      XLGNUM = LEGNUM
      XLCOD(1) = (XLCOD(1) - XLGNUM * 1000000.0) * 1000.0
      RETURN
      END
```

```
SUBROUTINE XTRACT(XNUMBR,XTRACL,XTRACX,XTRACR)
NXTRCL = XNUMBR / 1000.0
XTRACL = NXTRCL
XTRACX = XTRACL * 1000.
XTRACR = XNUMBR - XTRACX
RETURN
END
```

```
SUBROUTINE TIMCON (ARTDHM,TD,TF)
ND=ARTDHM/ 10000.0
AND = ND
ARTHM = ARTDHM - AND * 10000.0
NH = ARTHM/100.0
ANH = NH
ARTM = ARTHM - ANH * 100.0
 TEMT = ARTM + TD
NTEH = TEMT / 60.0
ANTEH = NTEH
TEM = TEMT - ANTEH * 60.0
NTED =(ANTEH +ANH)/24.0
ANTED=NTED
TEH=ANTEH + ANH - ANTED*24.0
TF = TEM + TEH * 100.0 + (ANTED + AND) * 10000.0
RETURN
END
```

```
      SUBROUTINE RNORM(SIGMA,RANDOM,IR)
      DIMENSION RAN(3)
      SUMRAN=0.
      DO 1 I=1,3
      CALL RAN1 (IR,RAN(I))
    1 SUMRAN=SUMRAN+RAN(I)
      RANDOM=2.0*SIGMA*(SUMRAN-1.5)
      RETURN
      END
```

```
SUBROUTINE RAN1(IY,ANS)
A=0.
B=1.
IY = 3125 * IY
IY = IY- (IY/67108864) * 67108864
FY = IY
ANS  = FY/67108864. *(B-A) + A
RETURN
END
```

```
      SUBROUTINE DEPTH(A,B,POLYCO,I,J,C,D,ZCOMP)
      DIMENSION POLYCO(45,45)
      ZCOMP = 0.
      IS = I
  548 POLY = POLYCO(IS,J)
      IT = J-1
  549 POLY = POLY*(B-C)+POLYCO(IS,IT)
      IF(IT-1)547,547,542
  542 IT = IT-1
      GO TO 549
  547 ZCOMP = ZCOMP*(A-D)+POLY
      IF(IS-1)550,550,544
  544 IS = IS-1
      GO TO 548
  550 RETURN
      END
```

```
      SUBROUTINE MOOR(XOUT,IIR,MXFLAG,XWD,MDLX,CASEP,FULDEP,REL)
      DIMENSION XOUT(30)
      CALL RAN1(IIR,RN)
      IF(CASEP-RN)93,94,94
   93 XOUT(4) = 1.
      GO TO 95
   94 CALL RAN1(IIR,RN)
      IF(FULDEP-RN)96,97,97
   96 XOUT(5) = 1.
      CALL RAN1(IIR,DPLP)
      XMDL=MDLX
      GO TO 98
   97 DPLP = 1.0
      XMDL=MDLX
   98 GO TO(115,116,117,117,115,116),MXFLAG
  117 PRINT 118,MXFLAG
  118 FORMAT(22H ERROR STOP. MXFLAG = ,I3//)
      GO TO 35
  115 ACTDPL = (XWD - XMDL)*DPLP
C     PRINT 2005,ACTDPL
C2005 FORMAT(/10H ACTDPL = ,F10.3/)
      GO TO 119
  116 ACTDPL = XMDL * DPLP
  119 CD = XWD - ACTDPL
      XOUT(20) = CD
      IF(CD)135,135,95
  135 XOUT(11) = 1.
   95 GO TO(120,120,127,127,128,128),MXFLAG
  127 PRINT 118,MXFLAG
      GO TO 35
  128 IF(XOUT(4)) 120,120,178
  178 XOUT(10) = 1.
      GO TO 35
  120 CALL RAN1(IIR,RN)
      IF(REL- RN)129,35,35
  129 XOUT(8)=1.
   35 RETURN
      END
```

```
      SUBROUTINE BOTTOM(XOUT,IIR,MXFLAG,XBTM,XPB,XNWL,REL)
      DIMENSION XOUT(30)
      XPB = XPB - (XPB/5.)* XBTM
      GO TO(201,201,202,203,201,201),MXFLAG
  201 PRINT 204,MXFLAG
  204 FORMAT(22H ERROR STOP. MXFLAG = ,I3//)
      GO TO 35
  202 CALL RAN1(IIR,RN)
      IF(XPB - RN) 205,205,206
  206 XOUT(22) = XNWL
      XOUT(6)=1.
      GO TO 205
  203 CALL RAN1(IIR,RN)
      IF(XPB - RN) 207,207,205
  207 XOUT(22)=XNWL
      XOUT(7)=1.
  205 CALL RAN1(IIR,RN)
      IF(REL -RN)226,35,35
  226 XOUT(8)=1.
   35 RETURN
      END
```

```
      SUBROUTINE TIMDIF(DHM1,DHM2,TDIF)
      DIMENSION DHM(2)
      DHM(1)=DHM1
      DHM(2)=DHM2
      DO 1 I=1,2
      ND=DHM(I)/10000.
      AND=ND
      NH=(DHM(I)-AND*10000.)/100.
      ANH=NH
    1 DHM(I)=DHM(I)-AND*10000.-ANH*100.+ANH*60.+AND*1440.
      TDIF=DHM(2)-DHM(1)
      RETURN
      END
```

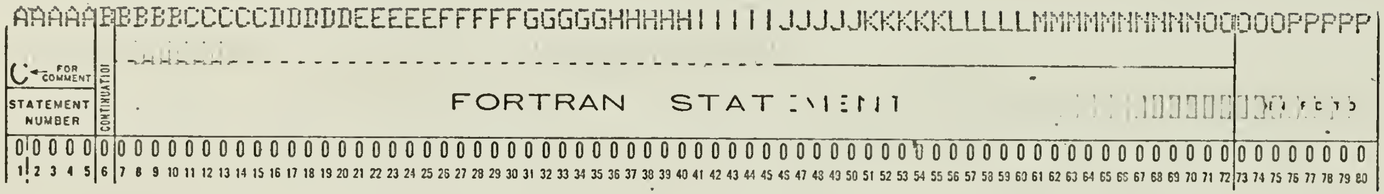
```
      SUBROUTINE POSIT(IR,B,A,G,S1,S2,D,E,X,Y)
      CALL RAN1(IR,RN)
      THETA = 6.28318*RN
      XMU = (A-B)/(G-B)
      CALL RAN1(IR,RN)
      IF(RN-XMU) 1,1,2
    2 RERROR = SQRTF((G-A)*(G-B)*(1.-RN))
      GO TO 3
    1 RERROR = B + SQRTF(RN*(G-B)*(A-B))
    3 X=S1 + RERROR*COSF(THETA) + D
      Y = S2 + RERROR*SINF(THETA) +E
      RETURN
      END
```

```fortran
SUBROUTINE TAPO(O,TIME,TYP,M1,M2,M3,M4,M5,NO,X,Y,W,MF)
DIMENSION O(30)
O(16)=TIME
O(17)=NO
O(18)=X
O(19)=Y
O(20)=W
O(21) = TYP
O(22) = M1
O(23)=M2
O(24)=M3
O(25)= M4
O(26)=M5
O(27)=MF
RETURN
END
```

PROGRAM MINEDEL

INPUT FORMAT

CARD NO. ONE
NUMBER OF CARDS REQUIRED = ONE

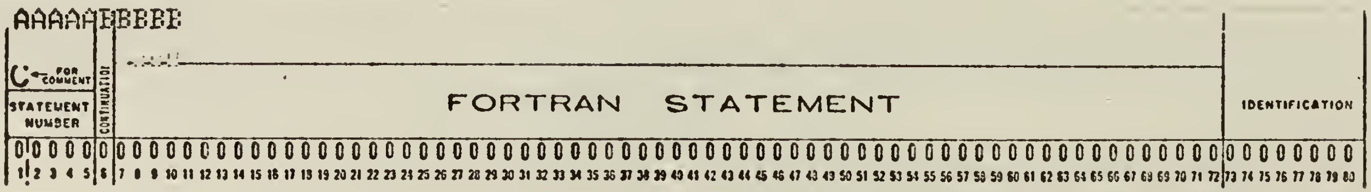


A.	I5	NV	TOTAL NUMBER OF VEHICLES.
B.	I5	NA	TOTAL NUMBER OF AIRCRAFT
C.	I5	NAT	TOTAL NUMBER OF AIRCRAFT TYPES.
D.	I5	NACR	NUMBER OF ROWS IN AIRCRAFT LEG DESCRIPTION LIST.(SAME AS TOTAL NUMBER OF LEGS ASSIGNED AIRCRAFT)
E.	I5	NACC	NUMBER OF COLUMNS IN AIRCRAFT LEG DESCRIPTION LIST.(SAME AS THE LEG WITH GREATEST NUMBER OF MINES ON IT AND EQUALS THE NUMBER OF MINES ON THAT LEG TIMES THREE PLUS SEVEN)
F.	I5	MACT	NUMBER OF AIRCRAFT DELIVERED MINE TYPES.
G.	I5	NSH	TOTAL NUMBER OF SHIPS.
H.	I5	NSHT	TOTAL NUMBER OF SHIP TYPES.
I.	I5	NSHR	NUMBER OF ROWS IN SHIP LEG DESCRIPTION LIST.(SAME AS TOTAL NUMBER OF LEGS ASSIGNED SHIPS)
J.	I5	NSHC	NUMBER OF COLUMNS IN SHIP LEG DESCRIPTION LIST.(SAME AS THE LEG WITH THE GREATEST NUMBER OF MINES ON IT AND EQUALS THE NUMBER OF MINES ON THAT LEG TIMES THREE PLUS SEVEN)

K.	I5	MSHT	NUMBER OF SHIP DELIVERED MINE TYPES.
L.	I5	NSU	TOTAL NUMBER OF SUBMARINES.
M.	I5	NSUT	TOTAL NUMBER OF SUBMARINE TYPES.
N.	I5	NSUR	NUMBER OF ROWS IN SUBMARINE LEG DESCRIPTION LIST.(SAME AS TOTAL NUMBER OF LEGS ASSIGNED SUBMARINES)
O.	I5	NSUC	NUMBER OF COLUMNS IN SUBMARINE LEG DESCRIPTION LIST.(SAME AS THE LEG WITH GREATEST NUMBER OF MINES ON IT AND EQUALS THE NUMBER OF MINES ON THAT LEG TIMES FIVE PLUS SEVEN)
P.	I5	MSUT	NUMBER OF SUBMARINE DELIVERED MINE TYPES.

NOTE-IF ANY OF THE FOREGOING INDICES EXCEEDS ITS CORRESPONDING VALUE IN THE PROGRAM DIMENSION STATEMENT,A PROGRAM CHANGE TO THE DIMENSION AND COMMON STATEMENTS IS REQUIRED.FURTHER IF THE TOTAL NUMBER OF MINES TO BE LAYED BY ANY SINGLE VEHICLE PLUS TWO TIMES THE NUMBER OF LEGS ASSIGNED THAT VEHICLE EXCEEDS THE DIMENSION OF THE TD ARRAY,THEN THE TD ARRAY MUST BE INCREASED TO EXCEED THAT NUMBER,AND THE UPPER INDICES ON THE DO LOOPS AT ONE STATEMENT BEFORE STATEMENT NO. 346 AND AT STATEMENT NO. 594 MUST BE ASSIGNED THAT DIMENSION VALUE MINUS ONE.

CARD NO. TWO
NUMBER OF CARDS REQUIRED = ONE



A.	I5	MINTOT	TOTAL NUMBER OF MINES.
B.	I6	NF	NUMBER OF POINTS USED TO DEFINE MINEFIELD PERIMETER.

NOTE-IF ANY OF THE FOREGOING INDICES EXCEEDS ITS CORRESPONDING VALUE IN THE PROGRAM DIMENSION STATEMENT, A PROGRAM CHANGE TO THE DIMENSION AND COMMON STATEMENTS IS REQUIRED.

CARD NO. THREE
NUMBER OF CARDS REQUIRED = TOTAL NUMBER OF VEHICLES (NV) IN CHRONOLOGICAL ORDER.
ARRAY NAME = VEHICLE ARRIVAL LIST (VAL,NV BY 11)

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AAAAAA.ABB.CC.DD.EE.FFFFFFFFF.GGGGGGGGG.HHHHHHHHH.IIIIIIIII.JJJJJJJJJ.KKKKKKKK.
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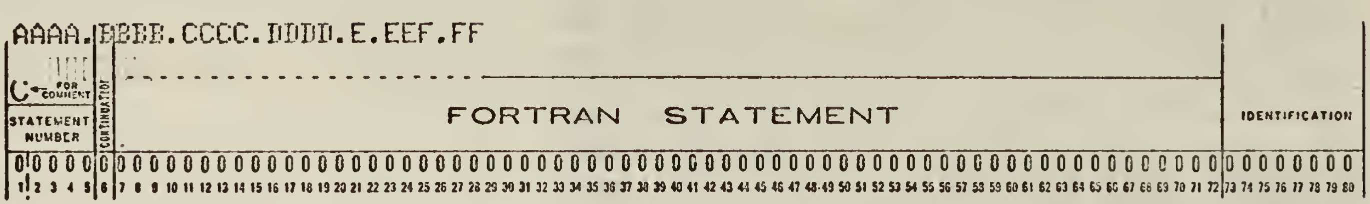
A.	F8.1	VAL(I,1)	DATE-TIME OF ARRIVAL OF ITH VEHICLE TO NEAREST TENTH OF A MINUTE.(EX.,080230.1)
B.	F3.0	VAL(I,2)	VEHICLE TYPE INDICATOR.(EX.,000-009 ARE SUBMARINE TYPES,010-099 ARE SHIP TYPES, 100-999 ARE AIRCRAFT TYPES)
C.	F3.0	VAL(I,3)	VEHICLE NUMBER WITHIN A GENERAL VEHICLE TYPE.(EX.,AIRCRAFT NO.1,SHIP NO.3,SUBMARINE NO.1)
D.	F3.0	VAL(I,4)	TOTAL NUMBER OF LEGS ASSIGNED THIS VEHICLE.(EX.,02 IMPLIES TWO LEGS ASSIGNED)
E.	F3.0	VAL(I,5)	NUMBER OF LOADED BOMBRACKS ON THIS AIRCRAFT. (EX., 04 IMPLIES FOUR LOADED BOMBRACKS. 000 IS INSERTED FOR SHIPS AND SUBMARINES)
F. THRU K.	F10.0 EACH	VAL(I,6) THRU VAL(I,11)	CODED LEG ASSIGNMENT LIST,STARTING WITH LEFT ELEMENT LEG NUMBERS ARE ASSIGNED IN THE ORDER THEY ARE TO BE TRANSVERSED BY THREE DIGIT SUB-GROUPS READING FROM LEFT TO RIGHT(EX.,VAL(I,6)= 002003006. AND VAL(I,7)= 25001000. IMPLIES THAT THE VEHICLE WILL TRANSIT LEGS NO. 2, 3, 6, 25, AND 1 IN THAT ORDER)

CARD NO. FOUR

NUMBER OF CARDS REQUIRED = TOTAL NUMBER OF AIRCRAFT TYPES (NAT) IN CONSECUTIVE ORDER OF AIRCRAFT TYPE NUMBER

ARRAY NAME = AIRCRAFT CHARACTERISTICS LIST (ACCL,NAT BY 6)



A.	F5.0	ACCL(J,1)	AIRCRAFT TYPE NUMBER.A THREE DIGIT NUMBER FROM 100 TO 999 INCLUSIVE (EX.,101).
B.	F5.0	ACCL(J,2)	AIRCRAFT TRANSIT SPEED IN KNOTS FOR THIS AIRCRAFT TYPE.
C.	F5.0	ACCL(J,3)	AIRCRAFT MINELAYING SPEED IN KNOTS FOR THIS AIRCRAFT TYPE.
D.	F5.0	ACCL(J,4)	AIRCRAFT MINELAYING ALTITUDE IN FEET FOR THIS AIRCRAFT TYPE.
E.	F4.2	ACCL(J,5)	PROBABILITY OF MINE RELEASE FOR THIS AIRCRAFT TYPE.
F.	F4.2	ACCL(J,6)	PROBABILITY OF SURVIVAL OVER OBJECTIVE AREA FOR THIS AIRCRAFT TYPE.

CARD NO. FIVE

NUMBER OR CARDS REQUIRED = TOTAL NUMBER OF AIRCRAFT MINE TYPES (MACT) IN CONSECUTIVE ORDER OF MINE TYPE NUMBER

ARRAY NAME = AIRCRAFT MINE CHARACTERISTICS LIST (ACMCL, MACT BY 14)

AAA.BBB.BBCCCCC.DDDDD.EEE.EEFFF.FFGGG.GGHHH.HHIII.IIJJ.KK.LLL.LLMMM.MMNNN.NN

STATEMENT NUMBER	CONTINUATION	FORTRAN STATEMENT	IDENTIFICATION
0 0 0 0 0	0	0 0 0 … 0	0 0 0 0 0 0 0 0
1 2 3 4 5	6	7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72	73 74 75 76 77 78 79 80

A.	F4.0	ACMCL(J,1)	MINE TYPE NUMBER.
B.	F6.2	ACMCL(J,2)	PROBABILITY OF CHUTE DEPLOYMENT FOR PARA-CHUTE EQUIPPED MINES. FOR THIS MINE TYPE. FOR NON-PARACHUTE EQUIPPED MINES INSERT 1.0.
C.	F6.0	ACMCL(J,3)	CEP IN YARDS FOR AN ALTITUDE OF 3000 FEET GIVEN PARACHUTE DEPLOYS FOR THIS MINE TYPE THIS IS ALSO CEP FOR NON-CHUTE EQUIPPED MINES.
D.	F6.0	ACMCL(J,4)	CEP IN YARDS FOR AN ALTITUDE OF 3000 FEET GIVEN PARACHUTE DOES NOT DEPLOY FOR THIS MINE TYPE.INSERT 00. FOR NON-CHUTE EQUIP-PED MINES.
E.	F6.2	ACMCL(J,5)	PROBABILITY OF WATER IMPACT DAMAGE GIVEN CHUTE DEPLOYS FOR THIS MINE TYPE. THIS IS ALSO PROBABILITY OF WATER IMPACT DAMAGE FOR NON-CHUTE EQUIPPED MINES.
F.	F6.2	ACMCL(J,6)	PROBABILITY OF WATER IMPACT DAMAGE GIVEN CHUTE DOES NOT DEPLOY FOR THIS MINE TYPE. INSERT 0.0 FOR NON-CHUTE EQUIPPED MINES.
G.	F6.2	ACMCL(J,7)	PROBABILITY OF IMPACT DAMAGE ON THE HARD-EST BOTTOM GIVEN THE WATER DEPTH IS LESS THAN 20 FEET AND CHUTE DEPLOYS FOR THIS MINE TYPE. THIS IS ALSO THE PROBABILITY OF IMPACT DAMAGE ON THE HARDEST BOTTOM GIVEN THE WATER DEPTH IS LESS THAN 20 FEET FOR NON-CHUTE EQUIPPED MINES.
H.	F6.2	ACMCL(J,8)	PROBABILITY OF IMPACT DAMAGE ON THE HARD-EST BOTTOM GIVEN THE WATER DEPTH IS LESS THAN 20 FEET AND CHUTE DOES NOT DEPLOY FOR THIS MINE TYPE. INSERT 0.00 FOR NON-CHUTE EQUIPPED MINES.

I.	F6.2	ACMCL(J,9)	PROBABILITY OF BURYING IN THE SOFTEST BOTTOM FOR THIS MINE TYPE.
J.	F3.0	ACMCL(J,10)	INDICATOR OF BOTTOM OR MOOR TYPE HAVING SIX POSSIBLE VALUES WHERE 1 AND 5 ARE MOORED OF FIXED CABLE LENGTH TYPE,2 AND 6 ARE MOORED OF FIXED CASE DEPTH TYPE BUT 5 AND 6 DO NOT ARM UNLESS CASE AND ANCHOR SEPARATION TAKES PLACE, 3 IS A BOTTOM MINE FOR WHICH BURYING IS UNDESIRABLE,AND 4 IS A BOTTOM MINE WHERE BURYING IS DESIREABLE.
K.	F3.0	ACMCL(J,11)	MINE TYPE I (NWL TYPE), KEY TO ACTUATION CURVES FOR MINES BURYING OR NOT BURYING WHICHEVER IS DESIREABLE FOR BOTTOM MINES OF THIS TYPE AND SHOULD REFLECT A DIMINISHED CAPABILITY. INSERT ZERO FOR MOORED MINES.
L.	F6.2	ACMCL(J,12)	PROBABILITY OF CASE AND ANCHOR SEPARATION FOR MOORED MINES ONLY.
M.	F6.2	ACMCL(J,13)	PROBABILITY OF FULL ANCHOR CABLE DEPLOYMENT FOR MOORED MINES ONLY.
N.	F6.2	ACMCL(J,14)	PROBABILITY THAT THE MINE WILL OPERATE GIVEN IT HAS NOT BEEN DAMAGED,I.E., THE MINES RELIABILITY.

CARD NO. SIX
NUMBER OF CARDS REQUIRED = TOTAL NUMBER OF AIRCRAFT (NA) IN CONSECUTIVE ORDER OF AIRCRAFT NUMBER.

ARRAY NAME = BOMBRACK ARRAY (BR,NA BY 6)

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AAAAAAAAA.BBBBBBBBB.CCCCCCCCC.DDDDDDDDD.EEEEEEEEE.FFFFFFFFF.
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STATEMENT NUMBER	CONTINUATION	FORTRAN STATEMENT	IDENTIFICATION
1 2 3 4 5	6	7 – 72	73 – 80

A. THRU F.	F10.0 EACH	BR(I,1) THRU BR(I,6)	ORDERED LIST OF THE MINES IN EACH OF SIX POSSIBLE AIRCRAFT BOMBRACKS BY THREE-DIGIT GROUPS FOR EACH MINE NUMBER IN ORDER OF RELEASE FROM RIGHT TO LEFT (EX.,001002027. IMPLIES MINES ARE STORED IN BOMBRACK IN TH ORDER 27,2,1 AND CAN ONLY BE RELEASED IN THAT ORDER.

CARD NO. SEVEN
NUMBER OF CARDS REQUIRED = TOTAL NUMBER OF MINES (MINTOT) IN CONSECUTIVE ORDER OF MINE NUMBER.
ARRAY NAME = MINE DESCRIPTION LIST (MDL, MINTOT BY 8)

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STATEMENT NUMBER	CONTINUATION	FORTRAN STATEMENT	IDENTIFICATION
1 2 3 4 5	6	7 – 72	73 – 80

A.	I5	MDL(J,1)	MINE CASE NUMBER.
B.	I5	MDL(J,2)	MINE TYPE II CORRESPONDS TO J INDEX TO RESPECTIVE MINE CHARACTERISTIC LIST. (EX., FOR A MINE WHICH IS AIRCRAFT LAYED AND IS TYPE NO. TWO ON THE AIRCRAFT MINE CHARACTERISTICS LIST, MDL(J,2) = 2.)

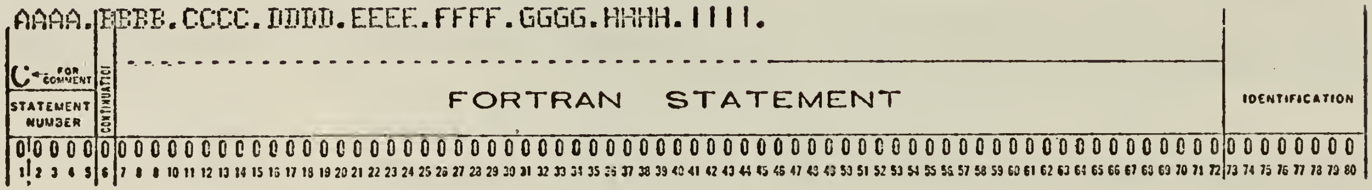
C.	I5	MDL(J,3)	MINE TYPE I, SPACE SAVED FOR INSERTING A KEY TO ACTUATION CURVES.
D.	I5	MDL(J,4)	CASE DEPTH, THE SETTING OF FEET BELOW SURFACE FOR FIXED CASE DEPTH MOORED MINES OR CABLE LENGTH (HEIGHT ABOVE BOTTOM) FOR FIXED CABLE LENGTH MOORED MINES.THIS VALUE IS ZERO FOR BOTTOM MINES.
E.	I8	MDL(J,5)	ARMING DELAY IN MINUTES FOR THIS MINE.
F.	I5	MDL(J,6)	STERILE TIME IN DAYS FOR THIS MINE.
G.	I5	MDL(J,7)	SHIP COUNT SETTING FOR THIS MINE.
H.	I5	MDL(J,8)	MOORING CABLE TYPE, KEY TO TYPE OF MOORING CABLE FOR MOORED MINES,I.E., 1 INDICATES ONE-HALF INCH WIRE CABLE AND 5 MIGHT INDICATE CHAIN FOR THIS MINE.

NOTE - EXCEPT FOR ITEMS A, B, C, D, AND E THE ITEMS ABOVE ARE NOT UTILIZED IN MINDEL AND THEY ARE INCLUDED ONLY AS A BOOKKEEPING FEATURE FOR THEIR USE IN ANY SUBSEQUENT THREAT ASSESSMENT MODEL.

CARD NO. EIGHT

NUMBER OF CARDS REQUIRED = TOTAL NUMBER OF SHIP TYPES (NSHT) IN CONSECUTIVE ORDER OF SHIP TYPE NUMBER.

ARRAY NAME = SHIP CHARACTERISTIC LIST (SHCL,NSHT BY 9)



A.	F5.0	SHCL(J,1)	SHIP TYPE NUMBER
B.	F5.0	SHCL(J,2)	TRANSIT SPEED IN KNOTS FOR THIS SHIP TYPE.
C.	F5.0	SHCL(J,3)	MINELAYING SPEED IN KNOTS FOR THIS SHIP TYPE.
D.	F5.0	SHCL(J,4)	ESTIMATE OF LEAST NAVIGATIONAL ERROR IN YARDS FOR THIS SHIP TYPE.

E.	F5.0	SHCL(J,5)	ESTIMATE OF AVERAGE NAVIGATIONAL ERROR IN YARDS FOR THIS SHIP TYPE.
F.	F5.0	SHCL(J,6)	ESTIMATE OF GREATEST NAVIGATIONAL ERROR IN YARDS FOR THIS SHIP TYPE.
G.	F5.0	SHCL(J,7)	PROBABILITY OF RELEASING A MINE ON THE FIRST ATTEMPT FOR THIS SHIP TYPE.
H.	F5.0	SHCL(J,8)	MAXIMUM TIME DELAY UNTIL MINE RELEASE AFTER A FAILURE ON FIRST ATTEMPT FOR THIS SHIP TYPE.
I.	F5.0	SHCL(J,9)	PROBABILITY OF SUFFERING SOME DAMAGE FOR THE FIRST HALF-HOUR IN THE MINELAYING OBJECTIVE AREA FOR THIS SHIP TYPE.

CARD NO. NINE
NUMBER OF CARDS REQUIRED = TOTAL NUMBER OF SHIP MINE TYPES (MSHT) IN CONSECUTIVE ORDER OF MINE TYPE NUMBER.
ARRAY NAME = SHIP MINE CHARACTERISTIC LIST(SHMCL, MSHT BY 8)

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C FOR COMMENT / STATEMENT NUMBER	CONTINUATION	FORTRAN STATEMENT	IDENTIFICATION
0 0 0 0 0	0	0000000000000000000000000000000000000000000000000000000000000000000	00000000
1 2 3 4 5	6	7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72	73 74 75 76 77 78 79 80

A.	F5.0	SHMCL(J,1)	MINE TYPE NUMBER
B.	F5.0	SHMCL(J,2)	PROBABILITY OF IMPACT DAMAGE ON THE HARDEST BOTTOM GIVEN THE WATER DEPTH LESS THAN 20 FEET FOR THIS MINE TYPE.
C.	F5.0	SHMCL(J,3)	PROBABILITY OF BURYING IN THE SOFTEST BOTTOM FOR BOTTOM MINES OF THIS TYPE. INSERT ZERO FOR MOORED MINES.
D.	F5.0	SHMCL(J,4)	INDICATOR OF BOTTOM OR MOOR TYPE MINE. SEE ITEM J OF ACMCL.

```
E.        F5.0      SHMCL(J,5)MINE TYPE I(NWL TYPE), KEY TO ACTUATION
                              CURVES FOR MINES BURYING OR NOT BURYING
                              WHICHEVER IS UNDESIRABLE FOR BOTTOM MINES
                              OF THIS TYPE AND SHOULD REFLECT A DIMINISH-
                              ED CAPABILITY. INSERT ZERO FOR MOORED MINES.
F.        F5.0      SHMCL(J,6)PROBABILITY OF CASE AND ANCHOR SEPARATION
                              FOR MOORED MINES OF THIS TYPE. INSERT ZERO
                              FOR BOTTOM MINES.
G.        F5.0      SHMCL(J,7)PROBABILITY OF FULL ANCHOR CABLE DEPLOY-
                              MENT FOR MOORED MINES OF THIS TYPE. INSERT
                              ZERO FOR BOTTOM MINES.
H.        F5.0      SHMCL(J,8)PROBABILITY THAT THE MINE WILL OPERATE GIV-
                              EN IT HAS NOT BEEN DAMAGED,I.E., THE MINES
                              RELIABILITY.
```

CARD NO. TEN
NUMBER OF CARDS REQUIRED = TOTAL NUMBER OF SUBMARINE TYPES (NSUT) IN CON-
SECUTIVE ORDER OF SUBMARINE TYPE NUMBER.
ARRAY NAME = SUBMARINE CHARACTERISTICS LIST(SUCL, NSUT BY 17)

A.BBBB.CCCC.DDDD.EEEE.FFFF..GGHH.H.II.JJ.KKLL.LMM.MMN.N.OO.PPQQQQQQQQQ.

C FOR COMMENT | STATEMENT NUMBER | CONTINUATION | FORTRAN STATEMENT | IDENTIFICATION

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A.        F2.0      SUCL(J,1) SUBMARINE TYPE NUMBER.
B.        F5.0      SUCL(J,2) SUBMARINE TRANSIT SPEED IN KNOTS FOR THIS
                              SUBMARINE TYPE.
C.        F5.0      SUCL(J,3) SUBMARINE MINELAYING SPEED IN KNOTS FOR
                              THIS SUBMARINE TYPE.
D.        F5.0      SUCL(J,4) ESTIMATE OF LEAST NAVIGATIONAL ERROR FOR
                              THIS SUBMARINE TYPE.
E.        F5.0      SUCL(J,5) ESTIMATE OF AVERAGE NAVIGATIONAL ERROR FOR
                              THIS SUBMARINE TYPE.
```

F.	F5.0	SUCL(J,6)	ESTIMAE OF GREATEST NAVIGATIONAL ERROR FOR THIS SUBMARINE TYPE.
G.	F3.2	SUCL(J,7)	PROBABILITY OF THE MINE BEING READY FOR FIRING FOR THIS SUBMARINE TYPE.
H.	F4.1	SUCL(J,8)	MAXIMUM TIME DELAY TO BE ALLOWED BEFORE SUBMARINE SKIPS THE LAYING OF A MINE FOR THIS SUBMARINE TYPE.
I.	F3.2	SUCL(J,9)	PROBABILITY OF DETECTION IN THE MINELAYING OBJECTIVE AREA FOR THIS SUBMARINE TYPE.
J.	F3.2	SUCL(J,10)	PROBABILITY OF KNOWLEDGE OF DETECTION GIVEN A DETECTION FOR THIS SUBMARINE TYPE. SHOULD REFLECT THE CHARACTERISTICS OF DETECTION SYSTEMS PRESENT.
K.	F3.2	SUCL(J,11)	PROBABILITY OF KNOWLEDGE OF DETECTION GIVEN NO DETECTION FOR THIS SUBMARINE TYPE. SHOULD REFLECT THE LIKLIHOOD THAT THE SUBMARINE WILL CONSIDER ITSELF DETECTED WHEN IN FACT IT WAS NOT DETECTED.
L.	F4.1	SUCL(J,12)	PROBABILITY OF SUSPENDING OPERATIONS GIVEN KNOWLEDGE OF DETECTION FOR THIS SUBMARINE TYPE. REFLECTS THE OPERATIONAL DOCTRINE DETECTED (= 1.0) OR TO CONTINUE OPS AT ALL COSTS (= 0.0).
M.	F4.1	SUCL(J,13)	PROBABILITY OF RETURNING TO MISSION GIVEN THAT THE MISSION HAS BEEN SUSPENDED FOR THIS SUBMARINE TYPE. REFLECTS THE OPERATIONAL DOCTRINE REQUIRING THE SUBMARINE TO RETURN AFTER SUSPENDING OPS (= 1.0) OR TO TERMINATE THE MISSION (= 0.0).
N.	F4.1	SUCL(J,14)	PROBABILITY OF RETURNING TO MISSION GIVEN THAT THE SUBMARINES SURVIVES AN ATTACK FOR THIS SUBMARINE TYPE. REFLECTS THE OPERATIONAL DOCTRINE REQUIRING THE SUBMARINE TO RETURN AFTER SURVIVING AN ATTACK (= 1.0) OR TERMINATE THE MISSION (= 0.0).

O.	F3.2	SUCL(J,15)	PROBABILITY OF AN ATTACK GIVEN A DETECTION REFLECTS THE LIKLIHOOD OF AN ATTACK FOLLOWING A DETECTION.
P.	F3.2	SUCL(J,16)	PROBABILITY OF A SUCCESSFUL ATTACK GIVEN AN ATTACK.
Q.	F10.0	SUCL(J,17)	APPROXIMATE DISTANCE FROM MINEFIELD CENTER TO ONE HUNDRED FATHOM CURVE.

CARD NO. ELEVEN
NUMBER OF CARDS REQUIRED = ONE

```
AAAAAAAA.A
C FOR COMMENT
STATEMENT NUMBER | CONTINUATION | FORTRAN STATEMENT | IDENTIFICATION
0 0 0 0 0 | 0 | 0000000000000000000000000000000000000000000000000000000000000000000 | 00000000
1 2 3 4 5 | 6 | 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 | 73 74 75 76 77 78 79 80
```

A.	F10.1	TAM.	DATE-TIME IN DAYS-HOURS-MINUTES TO NEAREST TENTH BY WHICH SUBMARINE OPERATIONS ARE TO BE TERMINATED. IF ONLY SUBMARINES ARE IN PLAY OR SUBMARINES ARE NOT FIRST IN THE OPERATION AREA, THEN A VALUE MUST BE PROVIDED. OTHERWISE A ZERO VALUE MAY BE INSERTED AND TAM IS SET BY THE PROGRAM TO THE TIME OF ARRIVAL OF THE NEXT VEHICLE WHICH IS NOT A SUBMARINE.

CARD NO. TWELVE
NUMBER OF CARDS REQUIRED = TOTAL NUMBER OF SUBMARINE MINE TYPES (MSUT) IN CONSECUTIVE ORDER OF MINE TYPE NUMBER.

ARRAY NAME = SUBMARINE MINE CHARACTERISTICS LIST (SUMCL, MSUT BY 13)

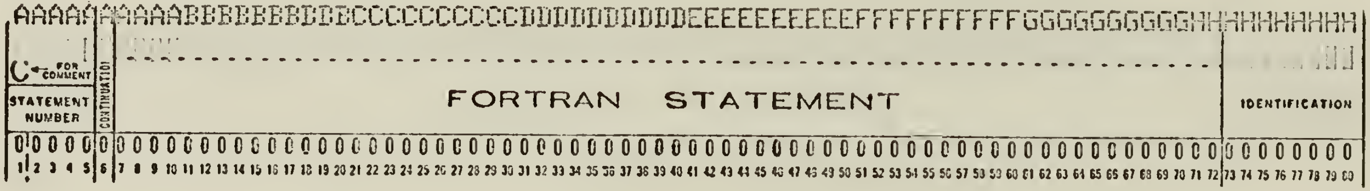
AAAA.BB.BBCC.CCDD.EEEE.FF.FFGG.GGHH.HHII.IIJJ.JJKK.KKLLLL.MM.MM

C ← FOR COMMENT / STATEMENT NUMBER	CONTINUATION	FORTRAN STATEMENT	IDENTIFICATION
0 0 0 0 0	0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
1 2 3 4 5	6	7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72	73 74 75 76 77 78 79 80

A.	F5.0	SUMCL(J,1)	MINE TYPE NUMBER
B.	F5.2	SUMCL(J,2)	PROBABILITY OF IMPACT DAMAGE ON THE HARDEST BOTTOM FOR THIS MINE TYPE. REFLECTS THE LIKLIHOOD MINE RETAINS SOME PROPULSIVE VELOCITY ON STRIKING BOTTOM.
C.	F5.2	SUMCL(J,3)	PROBABILITY OF BURYING IN SOFTEST BOTTOM FOR BOTTOM MINES OF THIS TYPE. INSERT ZERO FOR MOORED MINES.
D.	F3.0	SUMCL(J,4)	INDICATOR OF MOOR OR BOTTOM TYPE. SEE ITEM J OF ACMCL.
E.	F5.0	SUMCL(J,5)	MINE TYPE I,(NWL TYPE), KEY TO ACTUATION CURVES FOR MINES BURYING OR NOT BURYING WHICHEVER IS UNDESIRABLE FOR BOTTOM MINES OF THIS TYPE AND SHOULD REFLECT A DIMINISHED CAPABILITY. INSERT ZERO FOR MOORED MINES.
F.	F5.2	SUMCL(J,6)	PROBABILITY OF CASE AND ANCHOR SEPARATION FOR MOORED MINES OF THIS TYPE. INSERT ZERO FOR BOTTOM MINES.
G.	F5.2	SUMCL(J,7)	PROBABILITY OF FULL ANCHOR CABLE DEPLOYMENT FOR MOORED MINES OF THIS TYPE. INSERT ZERO FOR BOTTOM MINES.
H.	F5.2	SUMCL(J,8)	PROBABILITY OF A NORMAL RUN FOR A SELF-PROPELLED MINE OF THIS TYPE. INSERT ZERO FOR TYPES NOT SELF-PROPELLED.
I.	F5.2	SUMCL(J,9)	PROBABILITY OF MOTOR FAILURE GIVEN A FAILURE FOR SELF-PROPELLED MINES OF THIS TYPE. INSERT ZERO FOR TYPES NOT SELF-PROPELLED.

J.	F5.2	SUMCL(J,10)	PROBABILITY OF GYRO FAILURE GIVEN A FAILURE FOR SELF-PROPELLED MINES OF THIS TYPE. INSERT ZERO FOR TYPES NOT SELF-PROPELLED.
K.	F5.2	SUMCL(J,11)	PROBABILITY OF DEPTH CONTROL FAILURE GIVEN A FAILURE FOR SELF-PROPELLED MINES OF THIS TYPE. INSERT ZERO FOR TYPES NOT SELF-PROPELLED.
L.	F5.0	SUMCL(J,12)	CEP IN YARDS FOR A NORMAL RUN OF A SELF-PROPELLED MINE OF THIS TYPE. INSERT ZERO FOR TYPES NOT SELF-PROPELLED.
M.	F5.2		PROBABILITY THAT THE MINE WILL OPERATE GIVEN IT HAS NOT BEEN DAMAGED,I.E.; THE MINES RELIABILITY.

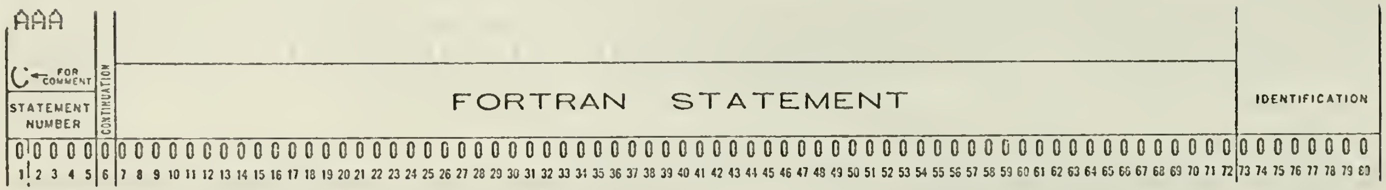
CARD NO. THIRTEEN
NUMBER OF CARDS REQUIRED = THIRTEEN
ARRAY NAME = MATRIX OF RANDOM NUMBER GENERATOR INITIALIZING VALUES (IRMAT, 100)



A. THRU H.	I10	IRMAT(J)	RANDOM NUMBER GENERATOR INITIALIZING VALUE FOR EACH ITERATION.

NOTE- THIRTEENTH CARD ONLY HAS ITEMS A. THRU D.

CARD NO. FOURTEEN
NUMBER OF CARDS REQUIRED = ONE



A. I3 NREP NUMBER OF REPETITIONS DESIRED.
NOTE - NREP CAN NOT EXCEED 100 WITHOUT INCREASING THE SIZE OF IRMAT.

VARIABLE NAMES

THOSE VARIABLE NAMES WHICH REPRESENT INPUT DATA ARE DISTINGUISED BY ASTERISKS.

```
ALPHA  = LOGF(PU+1.)/.7,USED IN CALCULATION OF PROB OF DAMAGE FOR SHIPS.
ANE    = AVERAGE NAVIGATIONAL ERROR (SHIPS AND SUBMARINES).   (*)
BNE    = BEST POSSIBLE NAVIGATIONAL ERROR (SHIPS AND AIRCRAFT). (*)
BTMTYP= BOTTOM TYPE VALUE.
CEP    = CIRCULAR PROBABLE ERROR USED FOR AIRCRAFT DROPPED MINES AND SELF
         -PROPELLED SUBMARINE LAYED MINES.   (*)
DELAY  = TIME DELAY VALUE USED FOR SHIP AND SUBMARINE MINE LAYING.
DRUN   = TOTAL RUN OF A SUBMARINE SELF-PROPELLED MINE WHICH SUFFERS A
         DEPTH FAILURE
DT     = VALUE OF DEAD(ATTRITION) TIME FOR AIRCRAFT, DAMAGE TIME FOR
         SHIPS,OR DETECTION EVENT TIME FOR SUBMARINES.
DX     = X-COMPONENT OF THE RANGE ERROR IN CALCULATION OF XPOSIT.
DY     = Y-COMPONENT OF THE RANGE ERROR IN CALCULATION OF YPOSIT.
ECCENT= ECCENTRICITY OF FLIGHT PATH OF AIRCRAFT DROPPED MINES.
GNE    = GREATEST NAVIGATIONAL ERROR (SHIPS AND SUBMARINES).   (*)
GYPHI  = RANDOM COURSE ERROR OF A SUBMARINE SELF-PROPELLED MINE WHICH HAS
         SUFFERED A GYRO FAILURE.
GYRUN  = RANDOM RUN OF A SUBMARINE SELF-PROPELLED MINE WHICH HAS SUFFERED
         A GYRO FAILURE.
HYP    = TOTAL RANGE ERROR FROM MINE INTENDED POSITION.
IABC   = DUMMY INDEX USED IN VEHICLE SELECTION LOOP.
IDAM   = DAMAGE TYPE FLAG(SHIPS)
IDET   = DETECTION EVENT FLAG(SUBMARINES)
IDET1  = DETECTION EVENT FLAG(SUBMARINES)
IDOT   = INDEX VALUE USED IN SUBMARINE MINES REMAINING ON BOARD STORE
         EVENT.
II     = INDEX VALUE USED IN TIME BETWEEN POINTS ON A LEG LOOP.
III    = INDEX VALUE USED IN INITIALIZING OUTPUT MATRIX.
IL     = INDEX VALUE USED IN LEG NUMBER DECODING EVENT.
IR     = INTEGER IDENTIFIER FOR RAN1 ROUTINE. (*)
IREP   = THE NUMBER OF THE REPETITION BEING PLAYED (INDEX VALUE)
```

```
ISUB   = INDEX VALUE USED IN SUBMARINE TAM DETERMINING EVENT.
I1,I2,= DUMMY VARIABLES USED IN THE CALCULATION OF TIME BETWEEN POINTS
I3,I4    ON A LEG.
J      = VEHICLE TYPE DESIGNATOR.
JCIG   = INDEX VALUE USED IN SUBMARINE DETECTION EVENT LOOP.
JI1    = INDEX USED IN SUBMARINE LEG DATA TEMPORARY STORAGE LOOP.
JI2    = INDEX USED IN SUBMARINE LEG DATA TEMPORARY STORAGE LOOP.
JIK    = INDEX USED IN SUBMARINE LEG DATA TEMPORARY STORAGE LOOP.
JJ     = VEHICLE TYPE IDENTIFIER.
JU     = INDEX USED IN SHIP TIME INCREMENT CORRECTION EVENT.
JUP    = INDEX USED IN SUBMARINE TIME INCREMENT CORRECTION EVENT.
K      = INDEX USED IN LEG LOOP
KK     = INDEX USED IN CALCULATION OF EVENT TIMES LOOP.
KKK    = INDEX USED IN SHIP AND AIRCRAFT LEG DATA TEMPORARY STORAGE LOOPS
L      = LEG NUMBER.
LDFLAG= SUBMARINE DETECTION EVENT FLAG.
LL1,2,
3AND4 = INDEXES USED FOR TEMPORARY STORAGE OF BOMBRACK MATRIX LOOPS.
MACT   = NUMBER OF AIRCRAFT MINE TYPES. (*)
MFLAG = MOOR OR BOTTOM TYPE INDICATOR.
MINTOT= TOTAL NUMBER OF MINES TO BE LAYED. (*)
MLFLAG= FLAG INDICATING WHEN OUTPUT MATRIX IS TO BE WRITTEN ON TAPE.
MM     = LEG EVENT INDICATOR.
MMAX   = DEGREE OF DEPTH CONTOUR POLYNOMIAL IN Y.  (*(TAPE))
MMAX1  = DEGREE OF BOTTOM CONTOUR POLYNOMIAL IN Y  (*(TAPE))
MQ     = INDEX TO ELEMENT OF TD ARRAY CONTAINING TOTAL TIME.
MR     = COUNTER FOR SUBMARINE MINES REMAINING ON BOARD.
MSHT   = NUMBER OF SHIP MINE TYPES. (*)
MSUT   = NUMBER OF SUBMARINE MINE TYPES. (*)
MT2    = MINE TYPE.
M1     = MINE NUMBER.
NA     = NUMBER OF AIRCRAFT  (*)
NACC   = NUMBER OF COLUMNS IN ACLDL. (*)
NACR   = NUMBER OF ROWS IN ACLDL. (*)
NAT    = NUMBER OF AIRCRAFT TYPES. (*)
```

```
NBR    = NUMBER OF BOMBRACKS PER AIRCRAFT.
NDAM   = SHIP DAMAGE TYPE INDICATOR.
NIL    = IL+5, DUMMY SUBSCRIPT USED IN LEG NUMBER DECODING EVENT.
NJ1,
NJ11,  = DUMMY VARIABLES USED IN SUBMARINE DATA TRANSFER EVENT.
NJ2,
NJ22
NLEGR  = NUMBER OF LEGS REMAINING FOR A VEHICLE.
NM     = INDEX TO MINE NUMBER IN ANY VEHICLE DESCRIPTION LIST.
NMAX   = DEGREE OF DEPTH.CONTOUR POLYNOMIAL IN X. (*(TAPE))
NMAX1  = DEGREE OF BOTTOM CONTOUR POLYNOMIAL IN X. (*(TAPE))
NMINES= NUMBER OF MINES TO BE LAYED ON A LEG.
NMIN   = INDEX FOR MINE LAYING LOOP.
NMINR  = INDEX FOR NUMBER OF MINES REMAINING LOOP IN ATTRITION EVENTS.
NREP   = NUMBER OF REPITIONS OF THE GAME, EACH REPITION USING A DIFFERENT
         VALUE OF IR.  (*)
NSH    = TOTAL NUMBER OF SHIPS. (*)
NSHC   = NUMBER OF COLUMNS IN SHLDL. (*)
NSHR   = NUMBER OF ROWS IN SHLDL. (*)
NSHT   = TOTAL NUMBER OF SHIP TYPES. (*)
NSU    = TOTAL NUMBER OF SUBMARINES. (*)
NSUC   = NUMBER OF COLUMNS IN SULDL. (*)
NSUR   = NUMBER OF ROWS IN SULDL. (*)
NSUT   = TOTAL NUMBER OF SUBMARINE TYPES. (*)
NTOTLG= TOTAL NUMBER OF LEGS ASSIGNED TO A VEHICLE. (*)
NUBR   = INDEX FOR AIRCRAFT MINE RELEASE EVENT.
NUBRS  = NUMBER OF BOMB RACKS FOR AN AIRCRAFT. (*)
NV     = TOTAL NUMBER OF VEHICLES THAT WILL TRANSIT MINEFIELD. (*)
NVEH   = VEHICLE NUMBER. (*)
N1     = NUMBER OF COLUMNS OF A LEG DESCRIPTION LIST USED FOR A LEG, AND
         INDEX FOR LEG DESCRIPTION LIST DATA TRANSFER EVENT.
N      = NUMBER OF TIME INCREMENTS ON A LEG.
PB     = PROBABILITY OF BURYING.
PD     = PROBABILITY OF A MINE BEING DAMAGED ON BOTTOM IMPACT.
```

```
PDAM   = PROBABILITY OF SHIP SUFFERING DAMAGE.
PDHB   = PROBABILITY OF A MINE BEING DAMAGED ON THE HARDEST BOTTOM. (*)
PU     = PROBABILITY OF A SHIP SUFFERING SOME DAMAGE DURING ITS FIRST
         HALF-HOUR IN THE MINEFIELD. (*)
RN     = A RANDOM (UNIFORM) NUMBER.
RUN    = DISTANCE TRAVELED BY A SUBMARINE FIRED SELF-PROPELLED MINE.
S      = VEHICLE MINE LAYING SPEED (YARDS/MIN).
SDELAY= TIME DELAY IN FIRING A SUBMARINE MINE.
SIGMA  = CEP/1.1744
T      = TIME PERIOD FOR WHICH THE PROBABILITY OF A SHIP SUFFERING DAMAGE
         BECOMES UNITY.
TAM    = TIME AT WHICH SUBMARINE MUST CEASE OPERATIONS IN MINEFIELD. (*)
TDIF   = TOTAL TIME(IN MINUTES) THAT A SUBMARINE HAS LEFT TO OPERATE IN
         THE MINEFIELD.
TDT    = TRUE EVENT TIME.
TDUM   = ADJUSTED MINE RELEASE TIME (SHIP).
TD100  = TRANSIT TIME FOR SUBMARINE FROM THE MINEFIELD TO THE 100 FATHOM
         CURVE.
TE     = INCREMENTAL TIME BETWEEN MINE INTENDED RELEASE POSITIONS ON A
         LEG.
TIP    = TRUE TIME OF A VEHICLE AT ITS INITIAL POSITION FOR A LEG.
TLAY   = TRUE TIME OF LAY OF A MINE.
TOTTIM= TOTAL TIME A VEHICLE WILL REMAIN IN MINEFIELD.
TPX    = X COORDINATE OF A VEHICLE TERMINAL POINT.
TPY    = Y COORDINATE OF A VEHICLE TERMINAL POINT.
TQ     = DIFFERENCE BETWEEN TDIF AND TD100 (TIME A SUBMARINE WILL HAVE
         LEFT TO OPERATE AFTER TRANSITING FROM THE 100 FATHOM CURVE TO THE
         MINEFIELD.
TREF   = ADJUSTED EVENT TIME FOR SUBMARINES.
TREF1,= ADJUSTED EVENT TIMES FOR SHIPS.
TREF2
TREM   = TIME REMAINING (FROM TOTTIM) FOR SUBMARINES.
TRET   = TIME A SUBMARINE RETURNS TO THE MINEFIELD.
TTP    = TRUE TIME OF ARRIVAL OF A VEHICLE AT A TERMINAL POINT.
TTRET  = TRUE TIME A SUBMARINE RETURNS TO THE MINEFIELD.
```

```
WD     = WATER DEPTH(FT)
XDELE  = DISTANCE TRAVELED IN THE X DIRECTION BY A SHIP DURING DELAY IN
         MINE RELEASE.
XE     = X ERROR IN FINAL MINE POSITION DUE TO NAVIGATIONAL ERROR OR CEP.
XIPX   = X COORDINATE OF A VEHICLE INITIAL POSITION.
XMEANX= MIDPOINT (X-AXIS) OF THE GRIDED RECTANGLE WHICH SURROUNDS THE
         MINEFIELD (SEE SURFIT DESCRIPTION). (*(TAPE))
XPOSIT= FINAL X COORDINATE OF A MINE.
XTRACL
XTRACR= UNPACKED PORTIONS OF CODED BOMB RACK WORD.
XTRACX
YDELE  = DISTANCE TRAVELED IN THE Y DIRECTION BY A SHIP DURING DELAY IN
         MINE RELEASE.
YE     = Y ERROR IN FINAL MINE POSITION DUE TO NAVIGATIONAL ERROR OR CEP.
YIPY   = Y COORDINATE OF A VEHICLE INITIAL POSITION.
YMEANY= MIDPOINT (Y-AXIS) OF THE GRIDED RECTANGLE WHICH SURROUNDS THE
         MINEFIELD (SEE SURFIT DESCRIPTION). (*(TAPE))
YPOSIT= FINAL X COORDINATE OF A MINE.


ARRAY NAMES

ACCL   = AIRCRAFT CHARACTERISTICS LIST
ACLDL  = AIRCRAFT LEG DESCRIPTION LIST
ACMCL  = AIRCRAFT MINE CHARACTERISTICS LIST
BOT    = MATRIX OF COEFFICIENTS OF BOTTOM-TYPE POLYNOMIAL
BR     = AIRCRAFT BOMB RACK LIST
BRTEMP= TEMPORARY STORAGE FOR BR
FXPTS  = LIST OF X COORDINATES OF POINTS DEFINING THE MINEFIELD
FYPTS  = LIST OF Y COORDINATES OF POINTS DEFINING THE MINEFIELD
IRMAT  = MATRIX OF IR VALUES
MDL    = MINE DESCRIPTION LIST
OUTPUT= MATRIX OF OUTPUT DATA FOR EACH MINE LAYED.
PHI    = MATRIX OF COEFFICIENTS OF THE DEPTH CONTOUR POLYNOMIAL
```

```
PROB  = LIST OF PROBABILITIES OF SUBMARINE DETECTION EVENTS.
SHCL  = SHIP CHARACTERISTIC LIST
SHLDL = SHIP LEG DESCRIPTION LIST
SHMCL = SHIP MINE CHARACTERISTIC LIST
SMROB = MATRIX OF MINES REMAINING ON BOARD A SUBMARINE THAT IS ATTRITED
        OR ABORTS ITS MISSION
SUCL  = SUBMARINE CHARACTERISTIC LIST
SULDL = SUBMARINE LEG DESCRIPTION LIST
SUMCL = SUBMARINE MINE CHARACTERISTIC LIST
TD.   = MATRIX OF RELATIVE EVENT TIMES
VAL   = VEHICAL ARRIVAL LIST
XLCOD = MATRIX OF CODED LEG ASSIGNMENTS
XLDL  = TEMPORARY STORAGE FOR VEHICLE LEG DATA
```

APPENDIX V

FLOWCHARTS FOR PROGRAM MINDEL

The succeeding pages of this appendix contain the flowcharts of the logic of program MINDEL and its subroutines. A list of the flowchart symbols used is shown in Figure 18. In addition to the normal application of these symbols, i.e., an appropriate symbol containing a FORTRAN statement, the processing rectangle containing a brief descriptive statement and with a number, e.g., 1. or 3.2, over the upper left-hand corner is used to summarize certain sections of the program as an aid in following the logic. A later flowchart with the same number appearing in a small box at the upper right-hand corner of the page and delineated by the terminal symbol with the words, "ENTRY" and "CONTINUE", contains further detail of the section summarized. Also, the connector numbers are consistent throughout the entire set of flowcharts with exception of the subroutine flowcharts. These flowcharts will greatly aid the user in understanding the commentary in the main body of this thesis as well as the program structure.

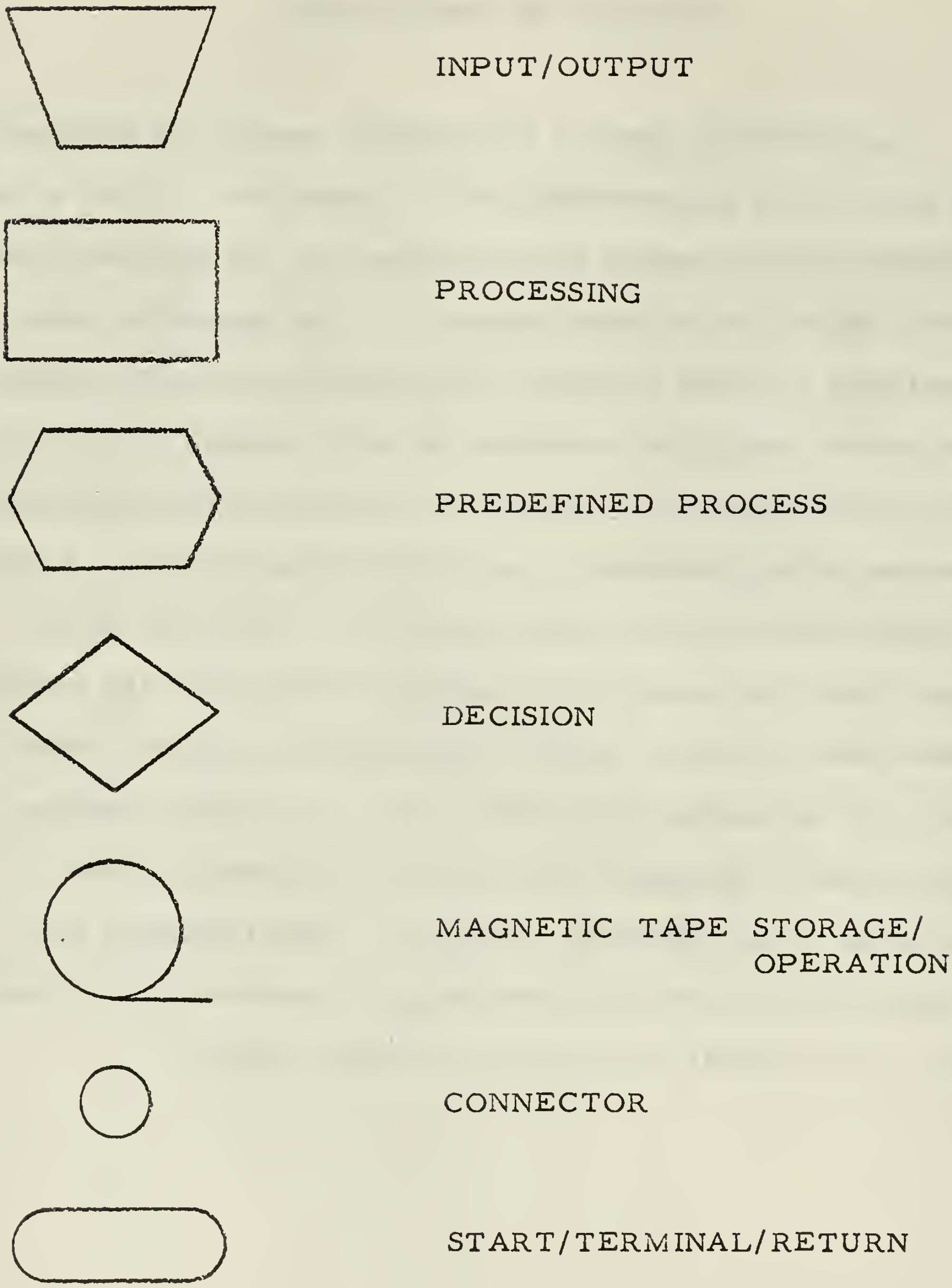
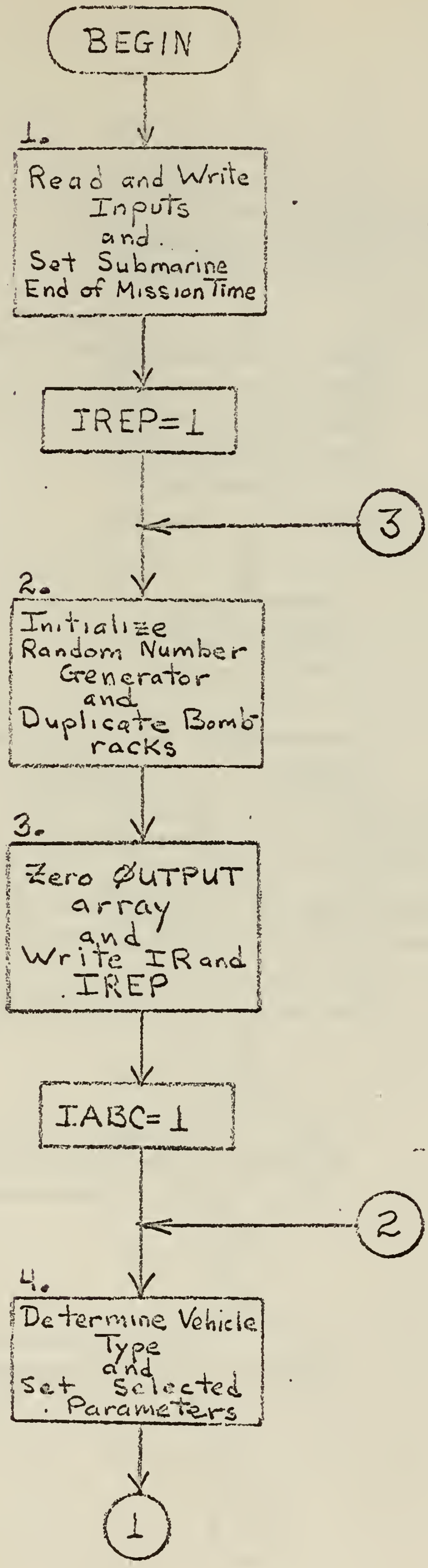
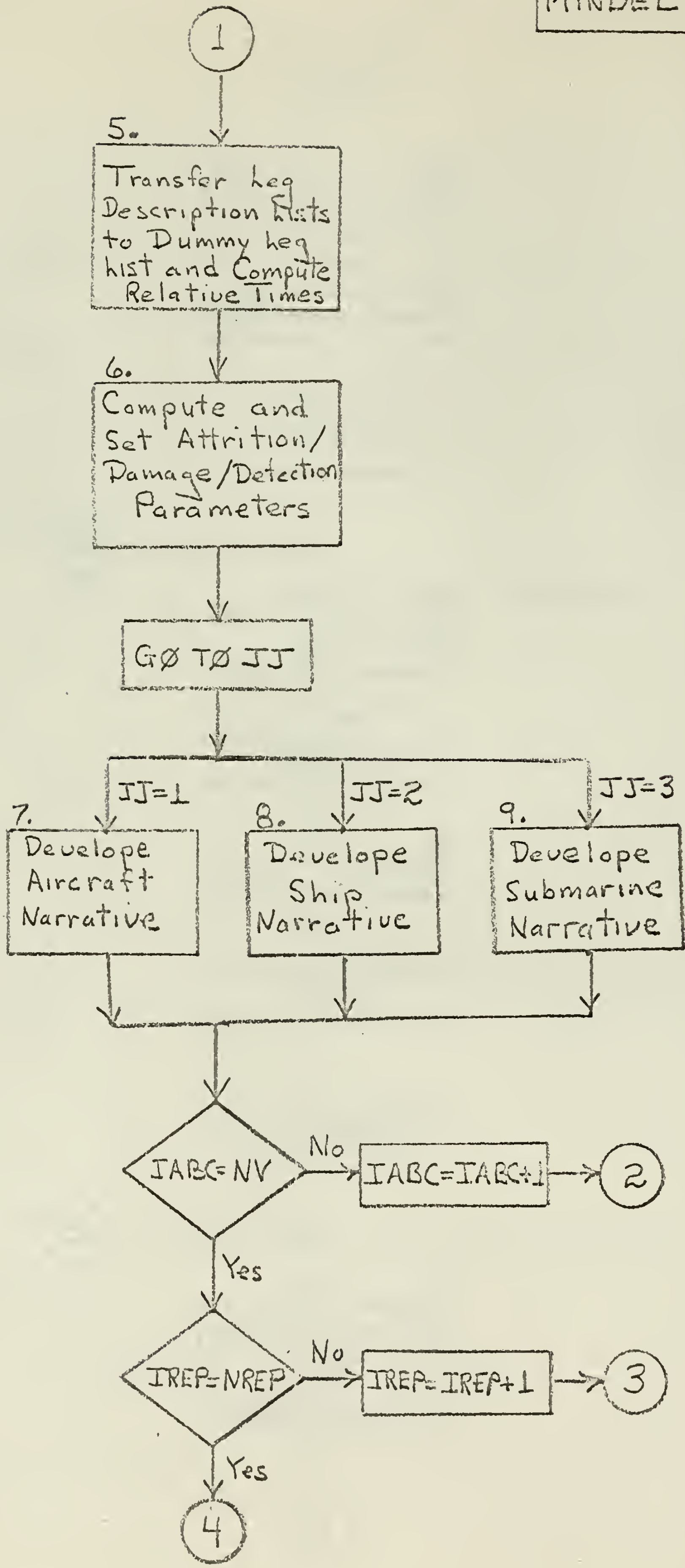


Figure 18. Flowchart Symbols

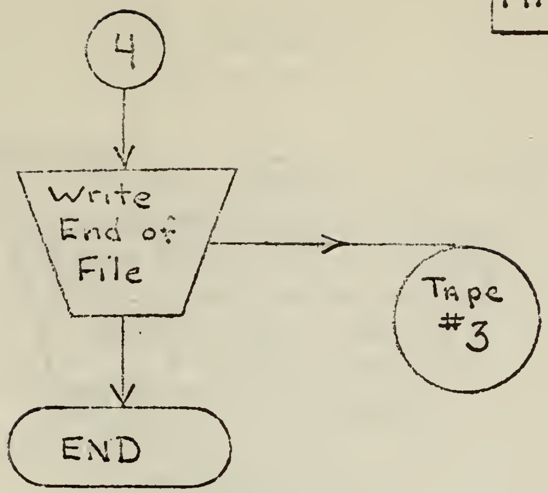
Program MINDEL

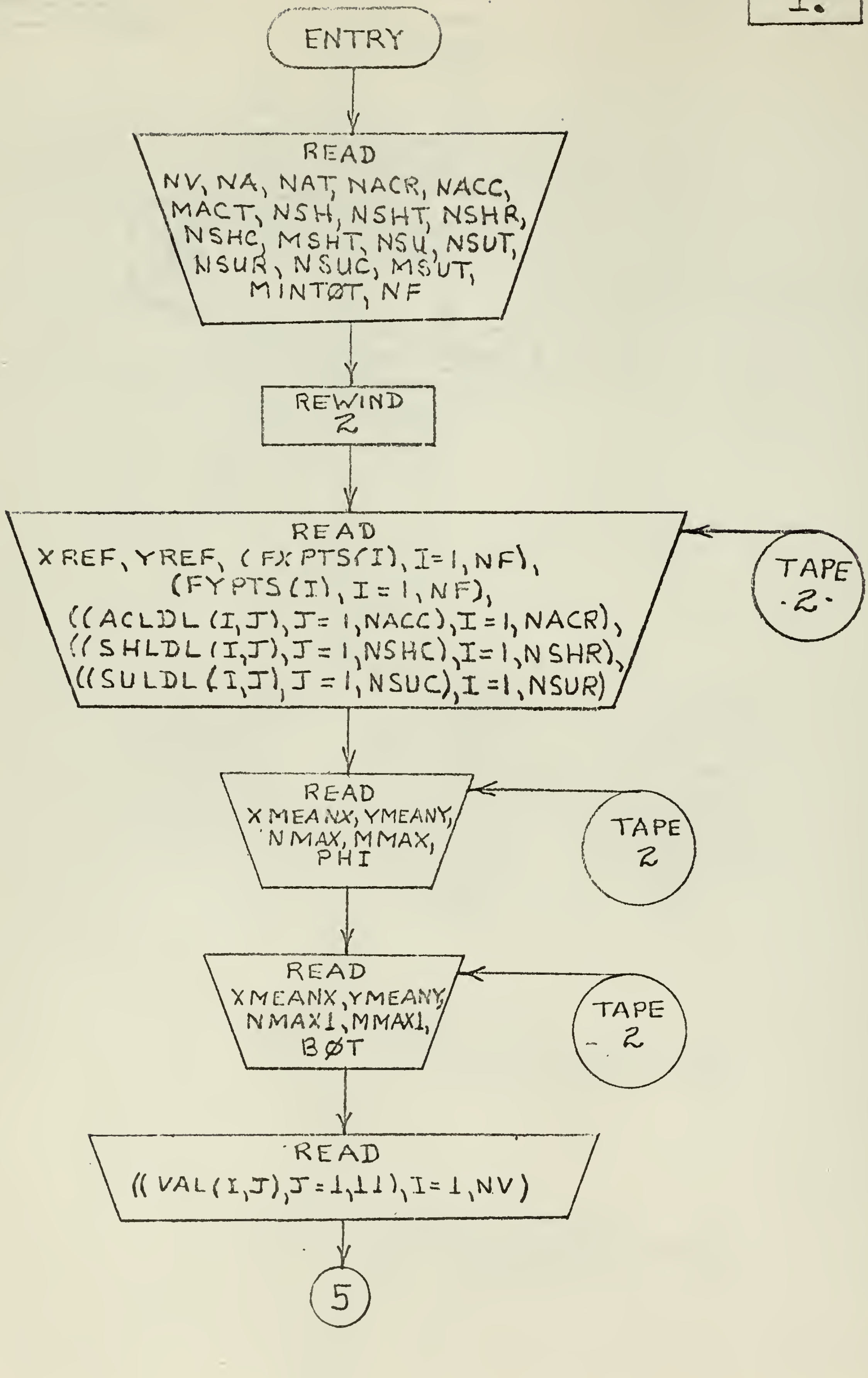




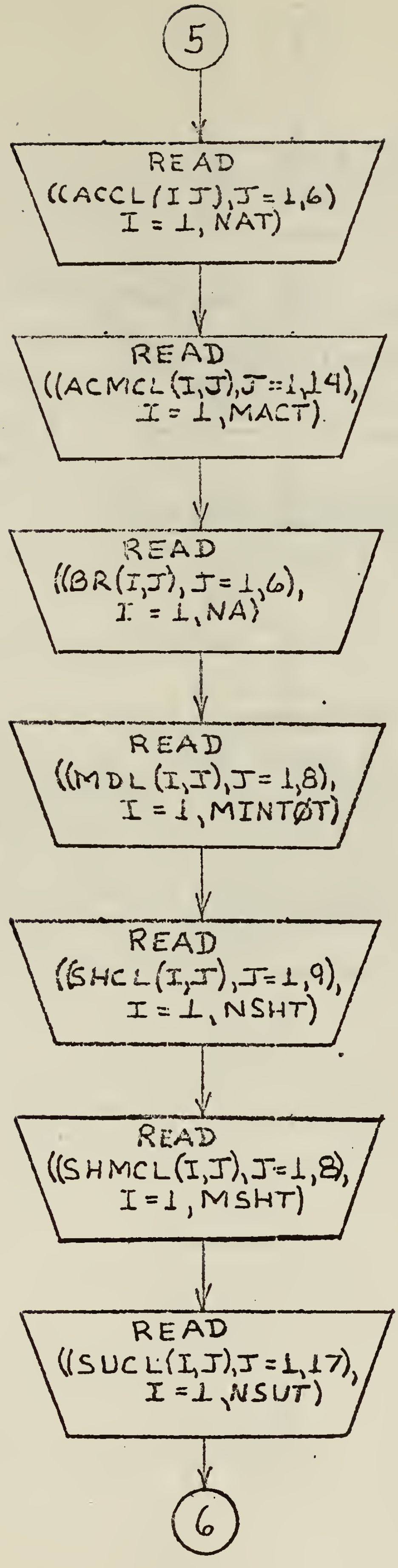
1
5.
Transfer Leg Description Lists to Dummy Leg List and Compute Relative Times
6.
Compute and Set Attrition/ Damage/Detection Parameters
GØ TØ JJ
JJ=1
JJ=2
JJ=3
7.
Develope Aircraft Narrative
8.
Develope Ship Narrative
9.
Develope Submarine Narrative
IABC=NV
No
IABC=IABC+1
2
Yes
IREP=NREP
No
IREP=IREP+1
3
Yes
4

MINDEL CONT'D

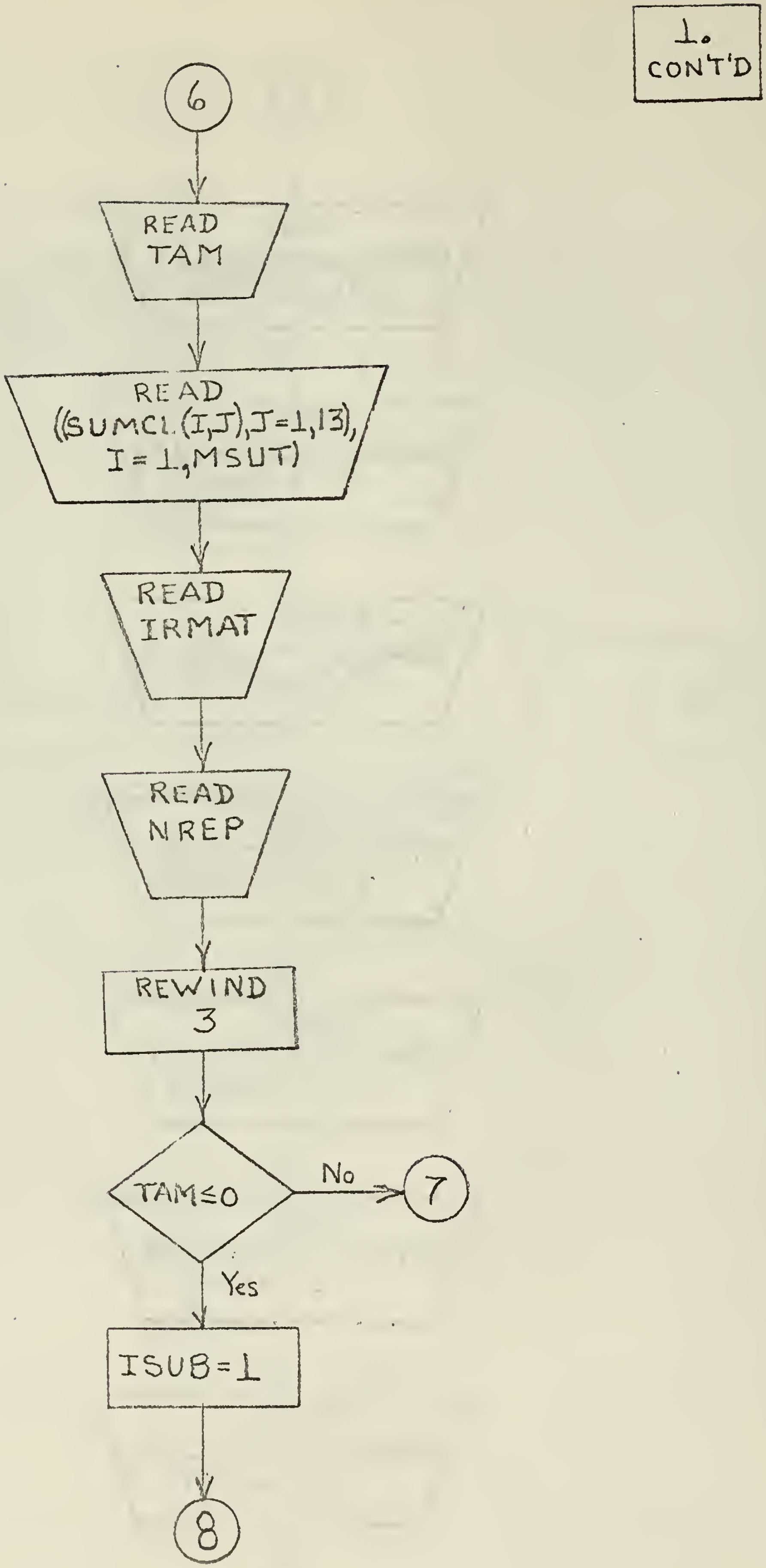


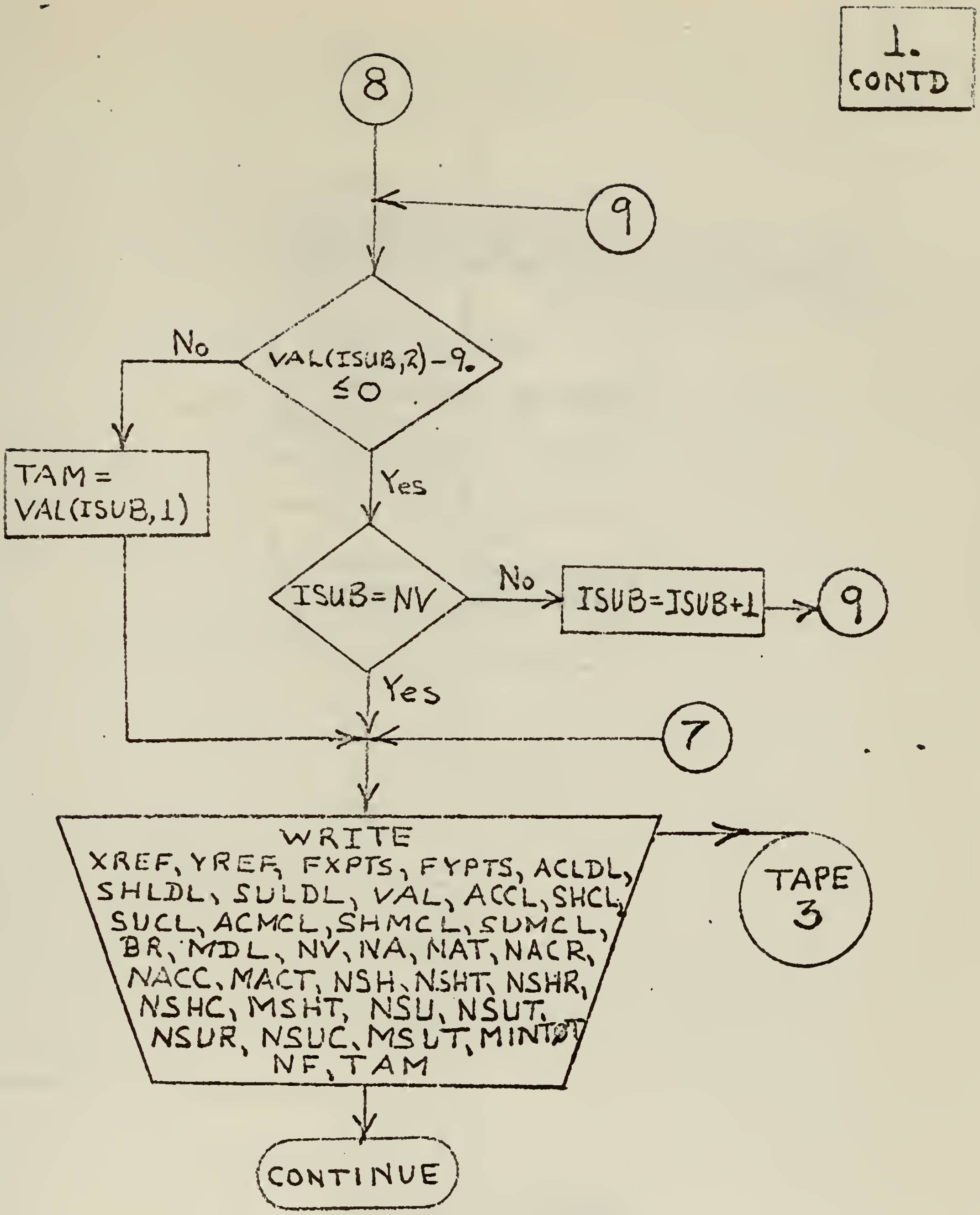

ENTRY
READ
NV, NA, NAT, NACR, NACC,
MACT, NSH, NSHT, NSHR,
NSHC, MSHT, NSU, NSUT,
NSUR, NSUC, MSUT,
MINTØT, NF
REWIND
2
READ
XREF, YREF, (FXPTS(I), I=1, NF),
(FYPTS(I), I=1, NF),
((ACLDL(I,J), J=1, NACC), I=1, NACR),
((SHLDL(I,J), J=1, NSHC), I=1, NSHR),
((SULDL(I,J), J=1, NSUC), I=1, NSUR)
TAPE
2
READ
XMEANX, YMEANY,
NMAX, MMAX,
PHI
TAPE
2
READ
XMEANX, YMEANY,
NMAX1, MMAX1,
BØT
TAPE
2
READ
((VAL(I,J), J=1,11), I=1, NV)
5

1.
CONTD



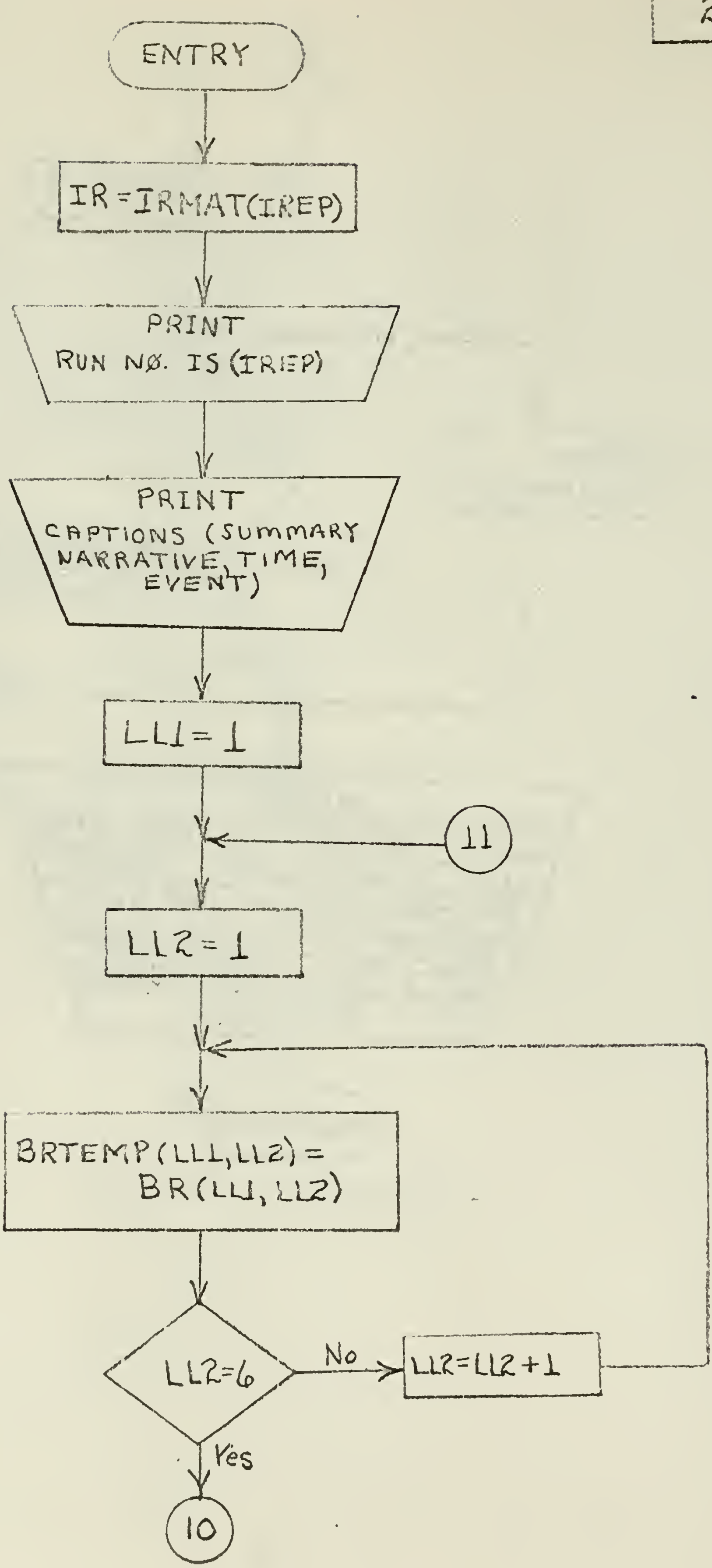
5
READ
((ACCL(IJ),J=1,6)
I = 1, NAT)
READ
((ACMCL(I,J),J=1,14),
I = 1,MACT).
READ
((BR(I,J), J=1,6),
I = 1,NA)
READ
((MDL(I,J),J= 1,8),
I = 1, MINTØT)
READ
((SHCL(I,J),J=1,9),
I = 1, NSHT)
READ
((SHMCL(I,J),J=1,8),
I=1, MSHT)
READ
((SUCL(I,J),J=1,17),
I =1,NSUT)
6


1.
CON'T'D
6
READ
TAM
READ
((SUMCL(I,J),J=1,13),
I=1,MSUT)
READ
IRMAT
READ
NREP
REWIND
3
TAM≤0
No
7
Yes
ISUB=1
8

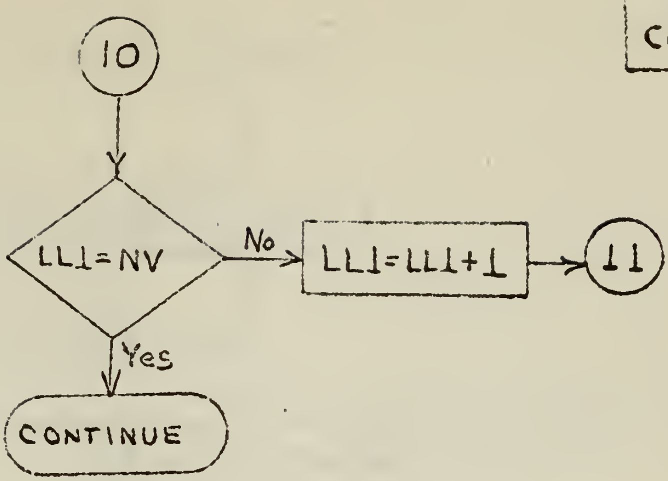


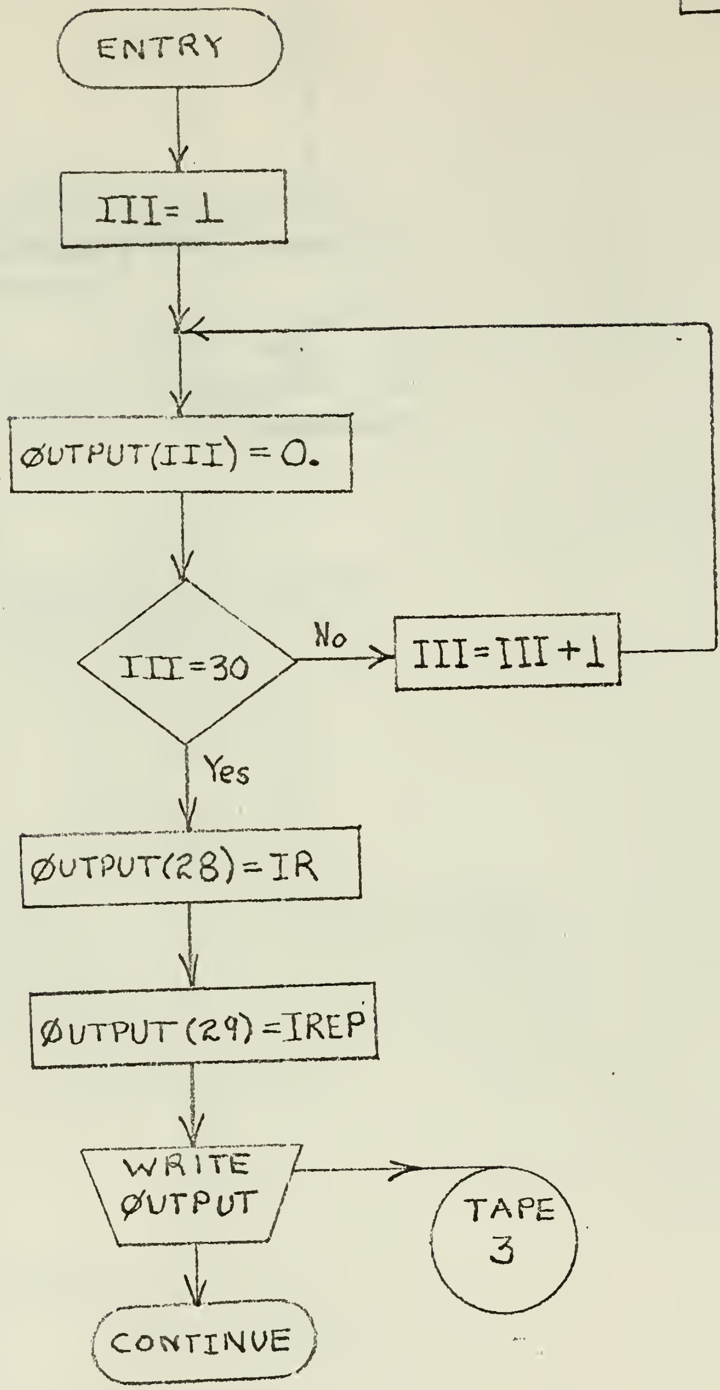
1. CONTD
8
9
No
VAL(ISUB,2)-9. ≤O
TAM = VAL(ISUB,1)
Yes
ISUB=NV
No
ISUB=ISUB+1
9
Yes
7
WRITE
XREF, YREF, FXPTS, FYPTS, ACLDL, SHLDL, SULDL, VAL, ACCL, SHCL, SUCL, ACMCL, SHMCL, SUMCL, BR, MDL, NV, NA, NAT, NACR, NACC, MACT, NSH, NSHT, NSHR, NSHC, MSHT, NSU, NSUT, NSUR, NSUC, MSUT, MINTOT NF, TAM
TAPE 3
CONTINUE

2.

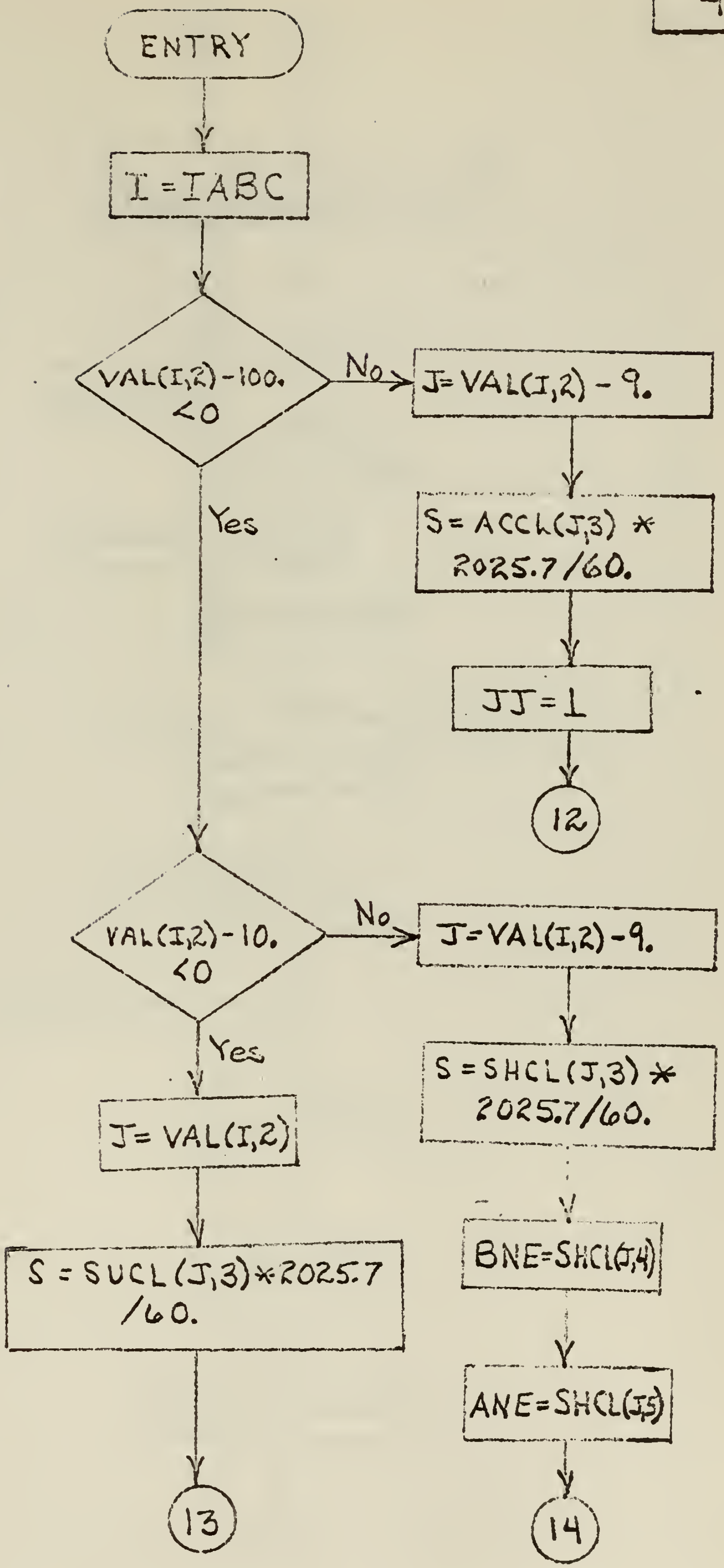

ENTRY
IR=IRMAT(IREP)
PRINT
RUN NØ. IS (IREP)
PRINT
CAPTIONS (SUMMARY
NARRATIVE, TIME,
EVENT)
LL1 = 1
11
LL2 = 1
BRTEMP(LL1,LL2) =
BR(LL1, LL2)
LL2=6
No
LL2=LL2+1
Yes
10

2. CONT'D



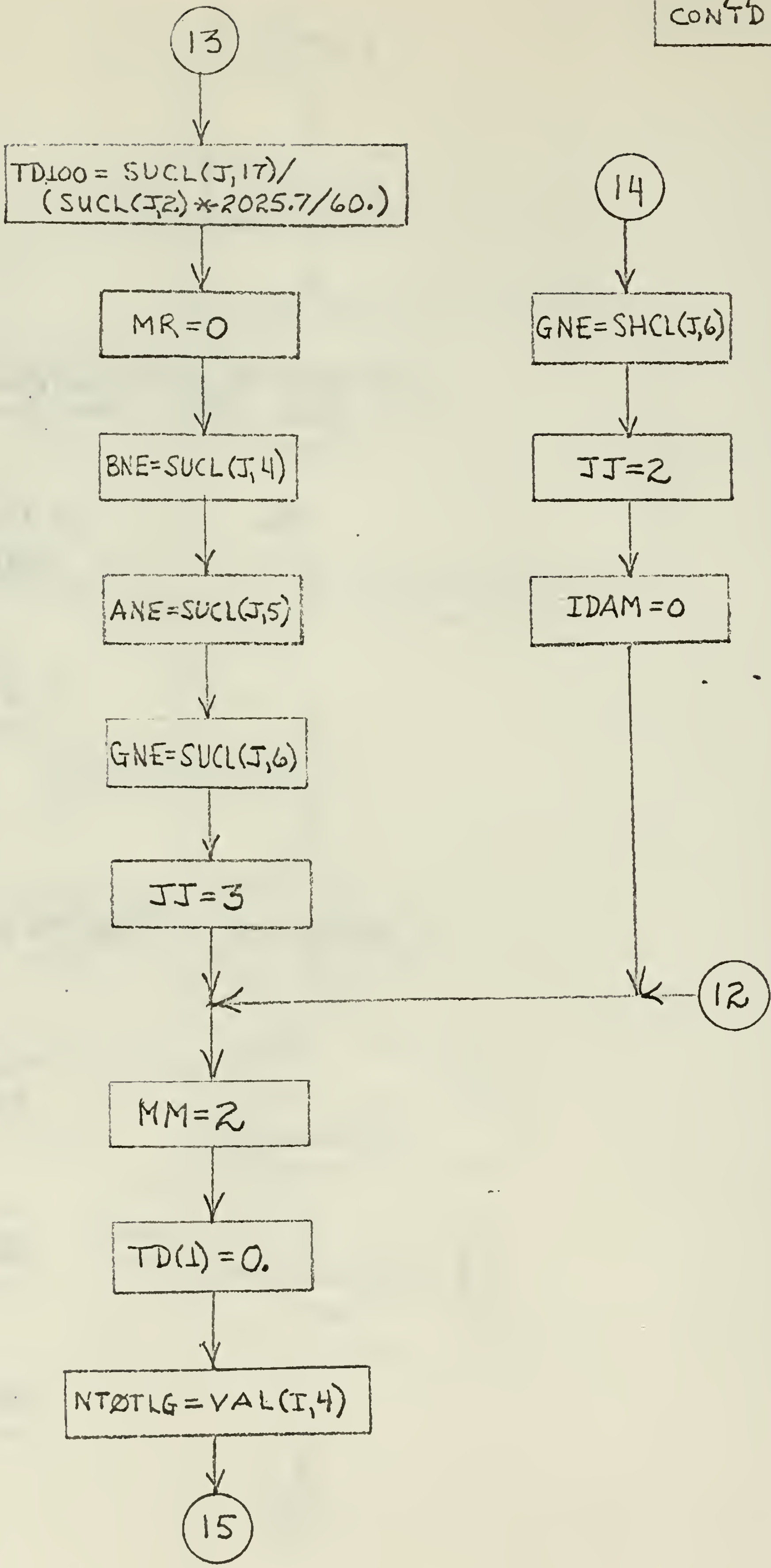

ENTRY
III = 1
ØUTPUT(III) = 0.
III=30
No
III = III + 1
Yes
ØUTPUT(28) = IR
ØUTPUT (29) = IREP
WRITE ØUTPUT
TAPE 3
CONTINUE

4.



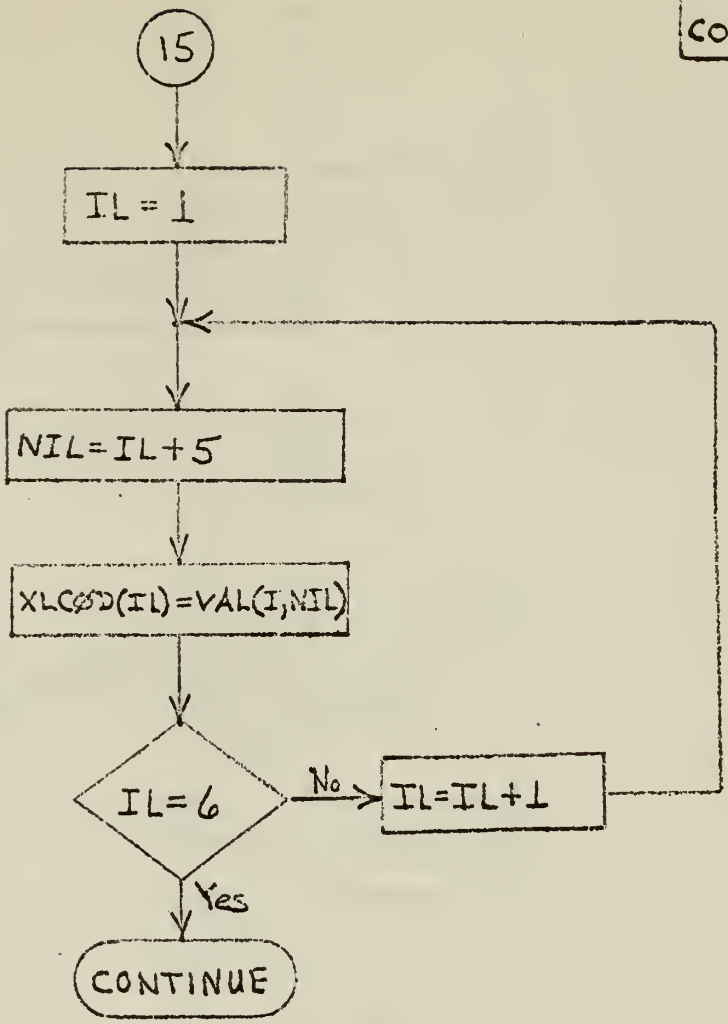
ENTRY
I = IABC
VAL(I,2) - 100. <0
No
J= VAL(I,2) - 9.
S = ACCL(J,3) *
2025.7/60.
JJ = 1
12
Yes
VAL(I,2) - 10. <0
No
J = VAL(I,2) - 9.
S = SHCL(J,3) *
2025.7/60.
BNE=SHCL(J,4)
ANE=SHCL(J,5)
14
Yes
J= VAL(I,2)
S = SUCL(J,3)*2025.7
/60.
13

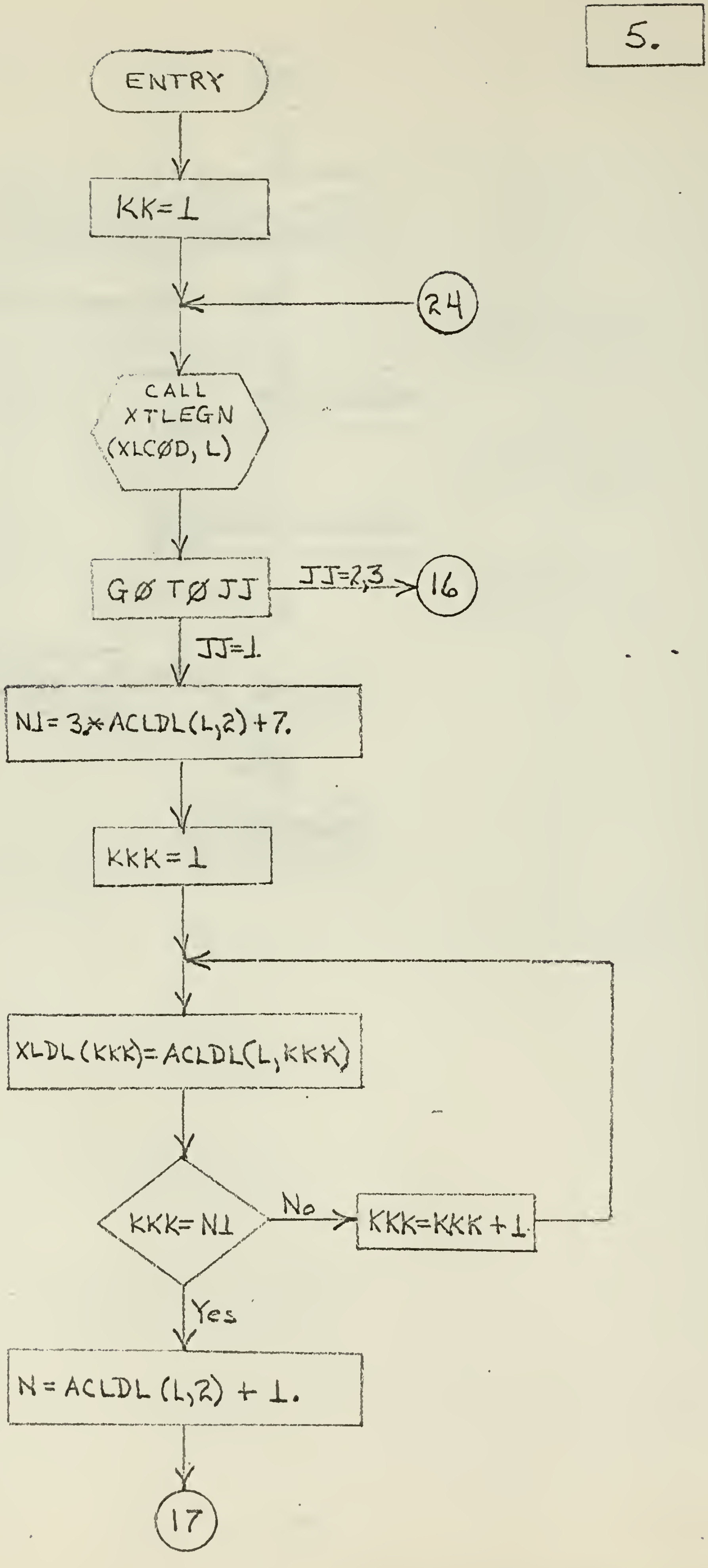
4. CONT'D

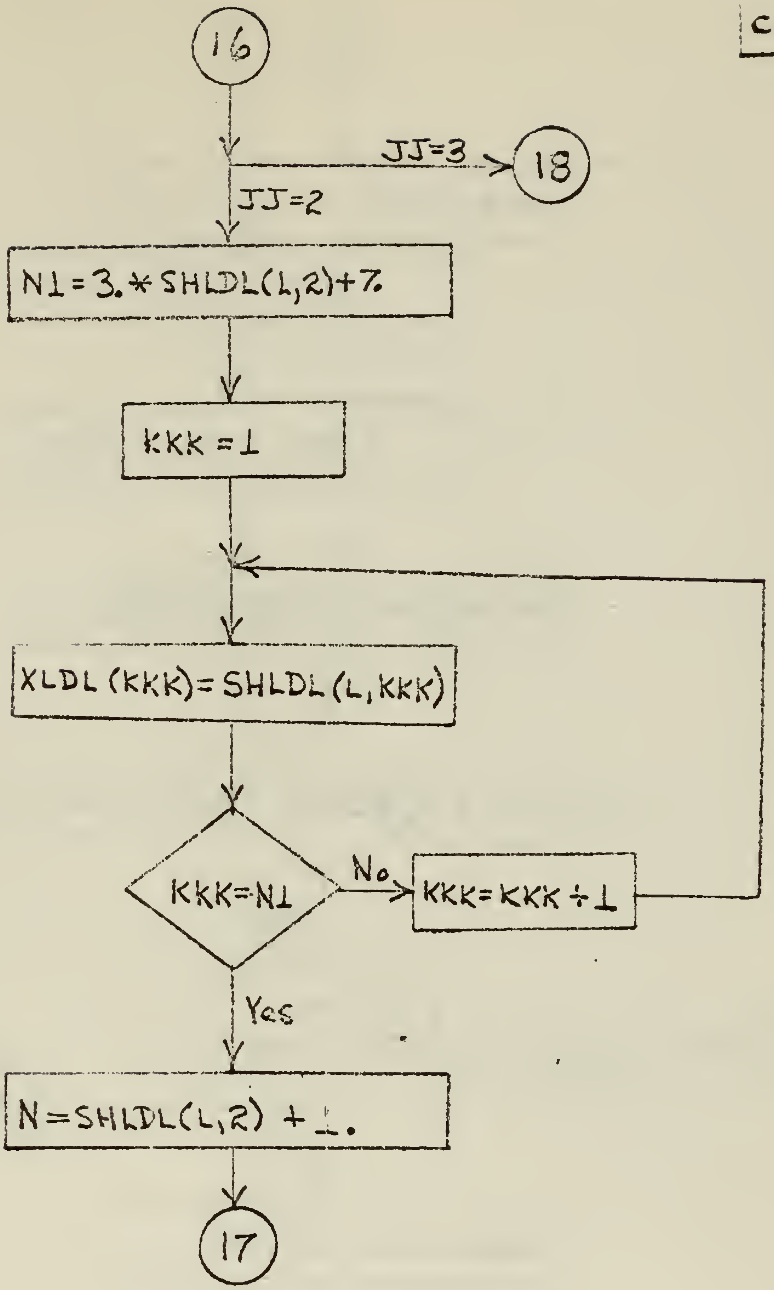


13
TD100 = SUCL(J,17)/ (SUCL(J,2) * 2025.7/60.)
MR=0
BNE=SUCL(J,4)
ANE=SUCL(J,5)
GNE=SUCL(J,6)
JJ=3
MM=2
TD(1)=0.
NTØTLG=VAL(I,4)
15
14
GNE=SHCL(J,6)
JJ=2
IDAM=0
12

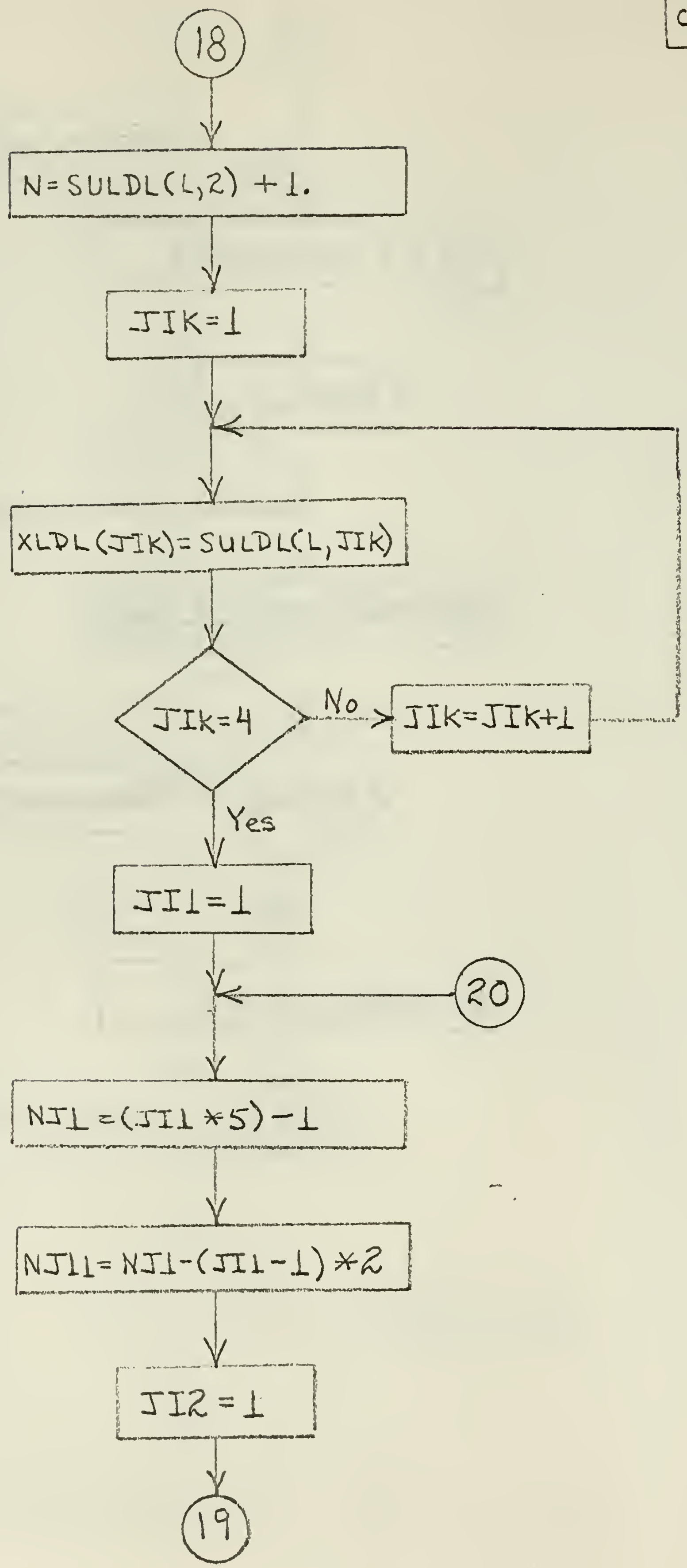
4.
CONT'D




5.
ENTRY
KK=1
24
CALL XTLEGN (XLCØD, L)
GØ TØ JJ
JJ=2,3
16
JJ=1
N1= 3.*ACLDL(L,2)+7.
KKK=1
XLDL(KKK)=ACLDL(L,KKK)
KKK=N1
No
KKK=KKK+1
Yes
N=ACLDL(L,2)+1.
17

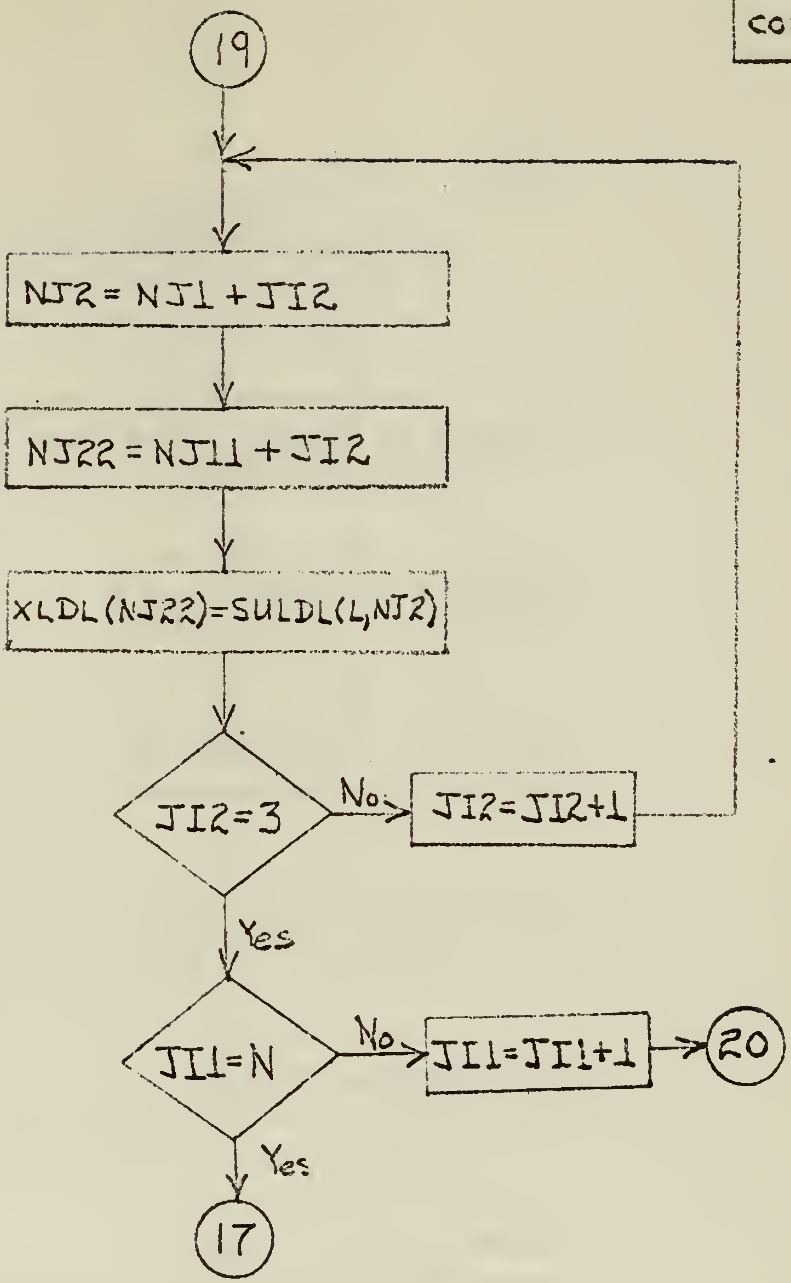

16
JJ=3
18
JJ=2
N1=3.*SHLDL(L,2)+7.
KKK=1
XLDL(KKK)=SHLDL(L,KKK)
KKK=N1
No
KKK=KKK+1
Yes
N=SHLDL(L,2)+1.
17

5.
CONT'D

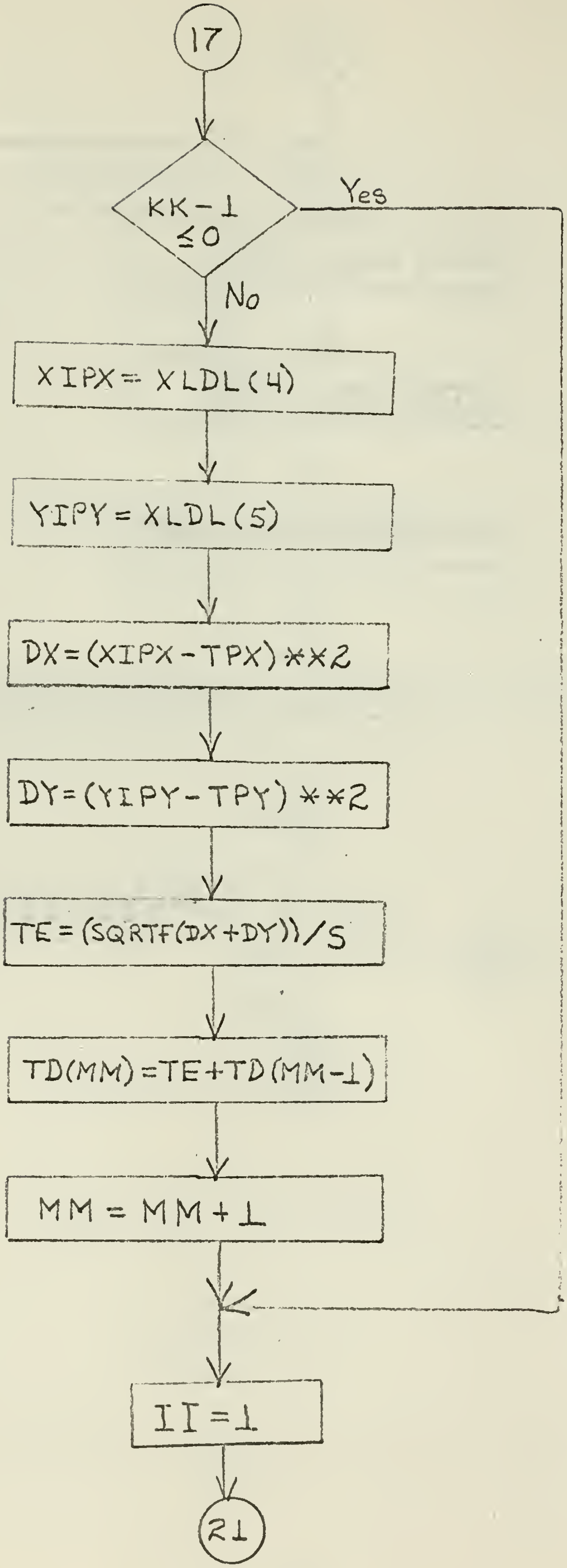


18
N=SULDL(L,2) +1.
JIK=1
XLDL(JIK)=SULDL(L,JIK)
JIK=4
No
JIK=JIK+1
Yes
JI1=1
20
NJ1 =(JI1 *5)-1
NJ11= NJ1-(JI1-1) *2
JI2 = 1
19

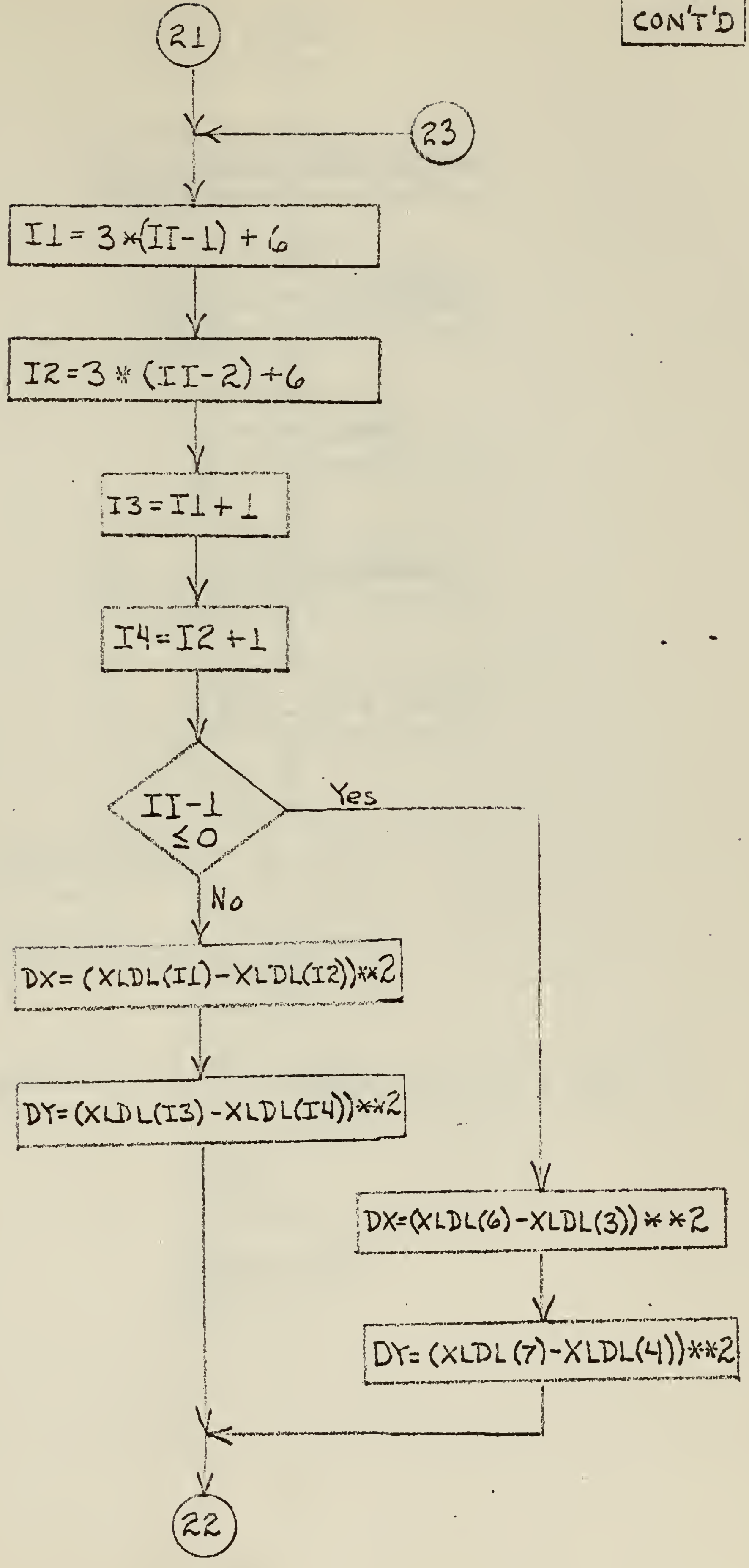
5. CON'T'D


19
NJ2 = NJ1 + JI2
NJ22 = NJ11 + JI2
XLDL(NJ22)=SULDL(L,NJ2)
JI2=3
No
JI2=JI2+1
Yes
JI1=N
No
JI1=JI1+1
20
Yes
17

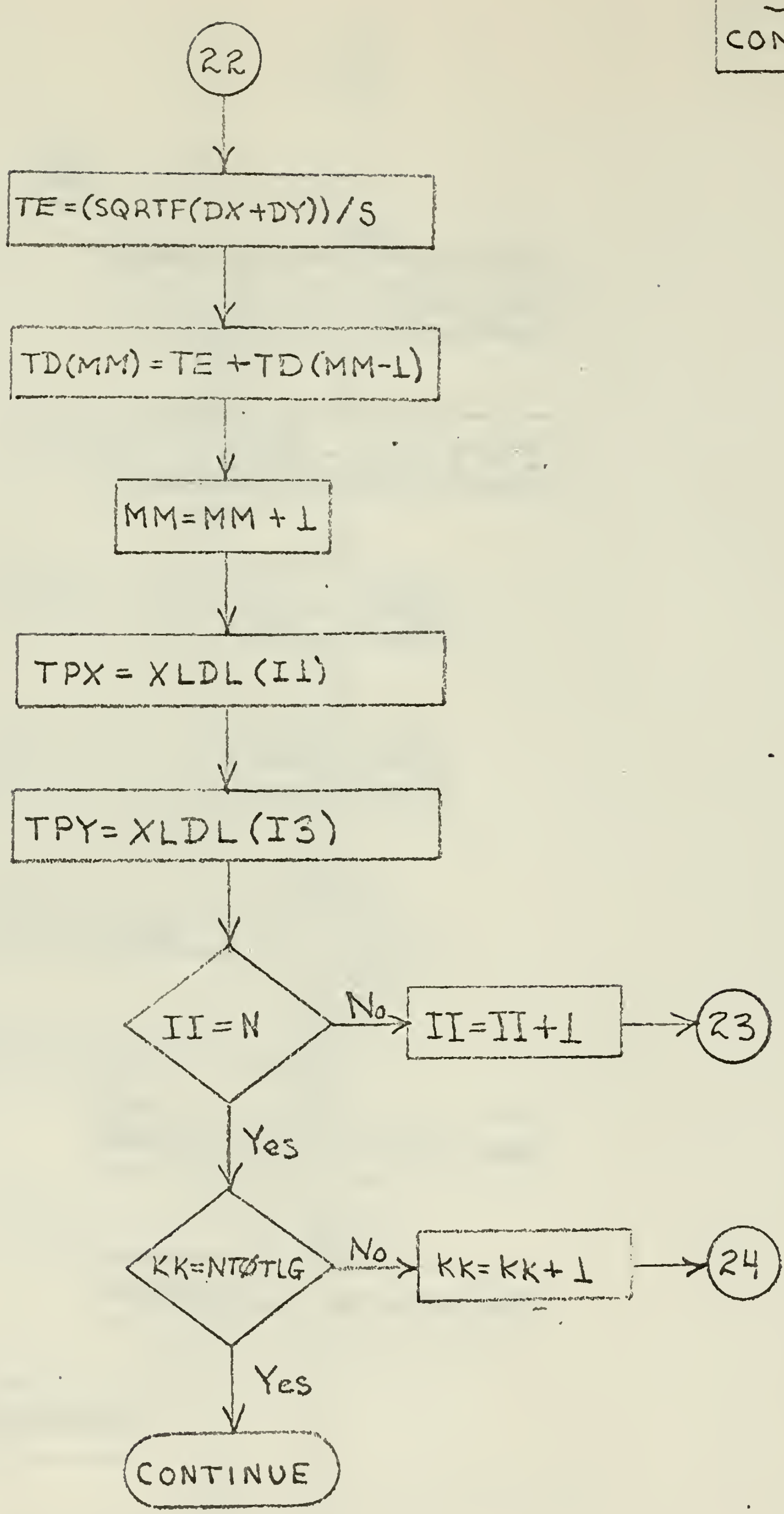
5.
CON'T'D


17
KK-1
≤0
Yes
No
XIPX = XLDL(4)
YIPY = XLDL(5)
DX = (XIPX - TPX) **2
DY = (YIPY - TPY) **2
TE = (SQRTF(DX + DY))/S
TD(MM) = TE + TD(MM-1)
MM = MM + 1
II = 1
21

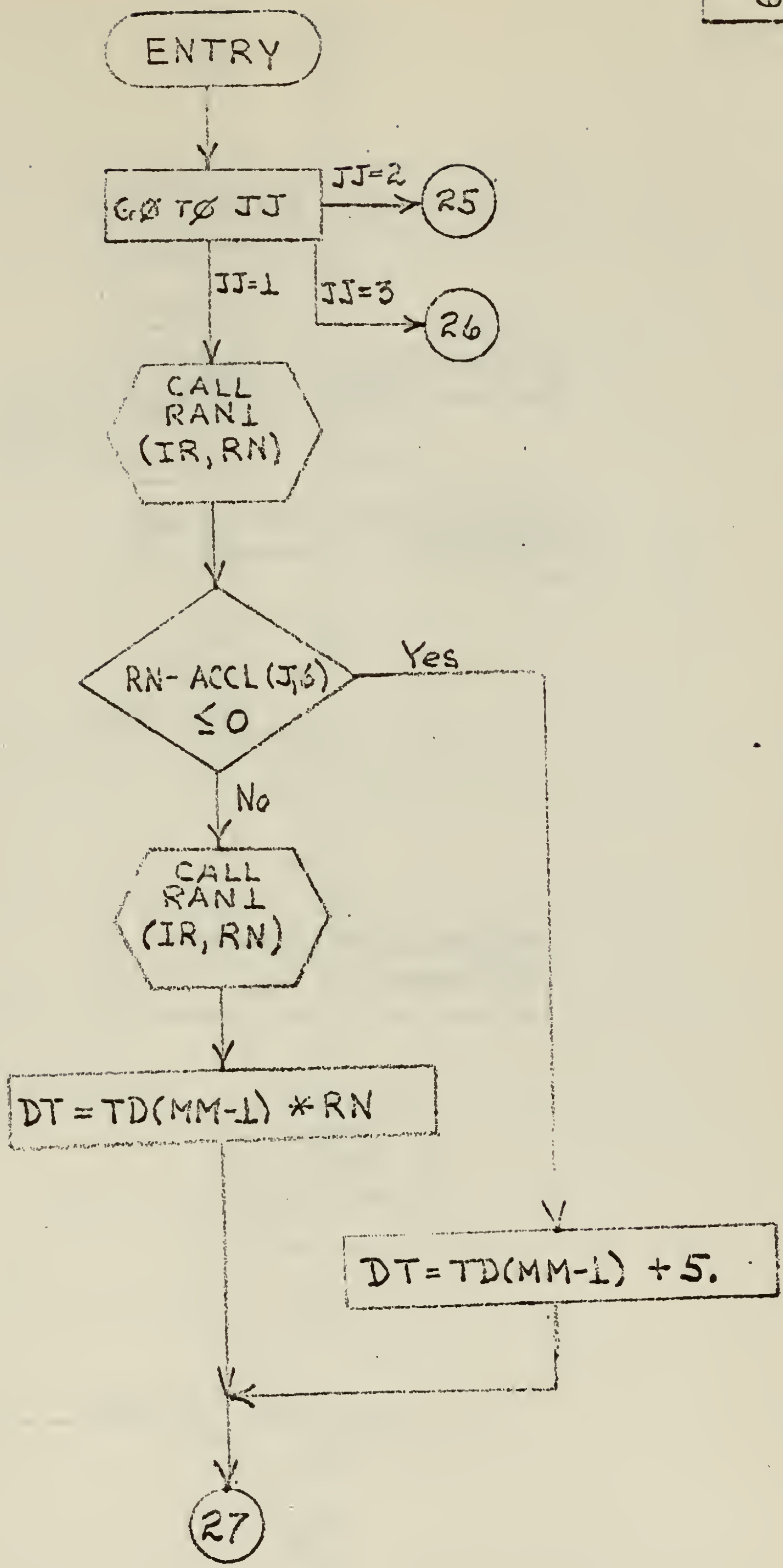
5.
CON'T'D


21
23
I1 = 3*(II-1) + 6
I2 = 3*(II-2) + 6
I3 = I1 + 1
I4 = I2 + 1
II-1 ≤ 0
Yes
No
DX= (XLDL(I1)-XLDL(I2))**2
DY= (XLDL(I3)-XLDL(I4))**2
DX=(XLDL(6)-XLDL(3))**2
DY= (XLDL(7)-XLDL(4))**2
22

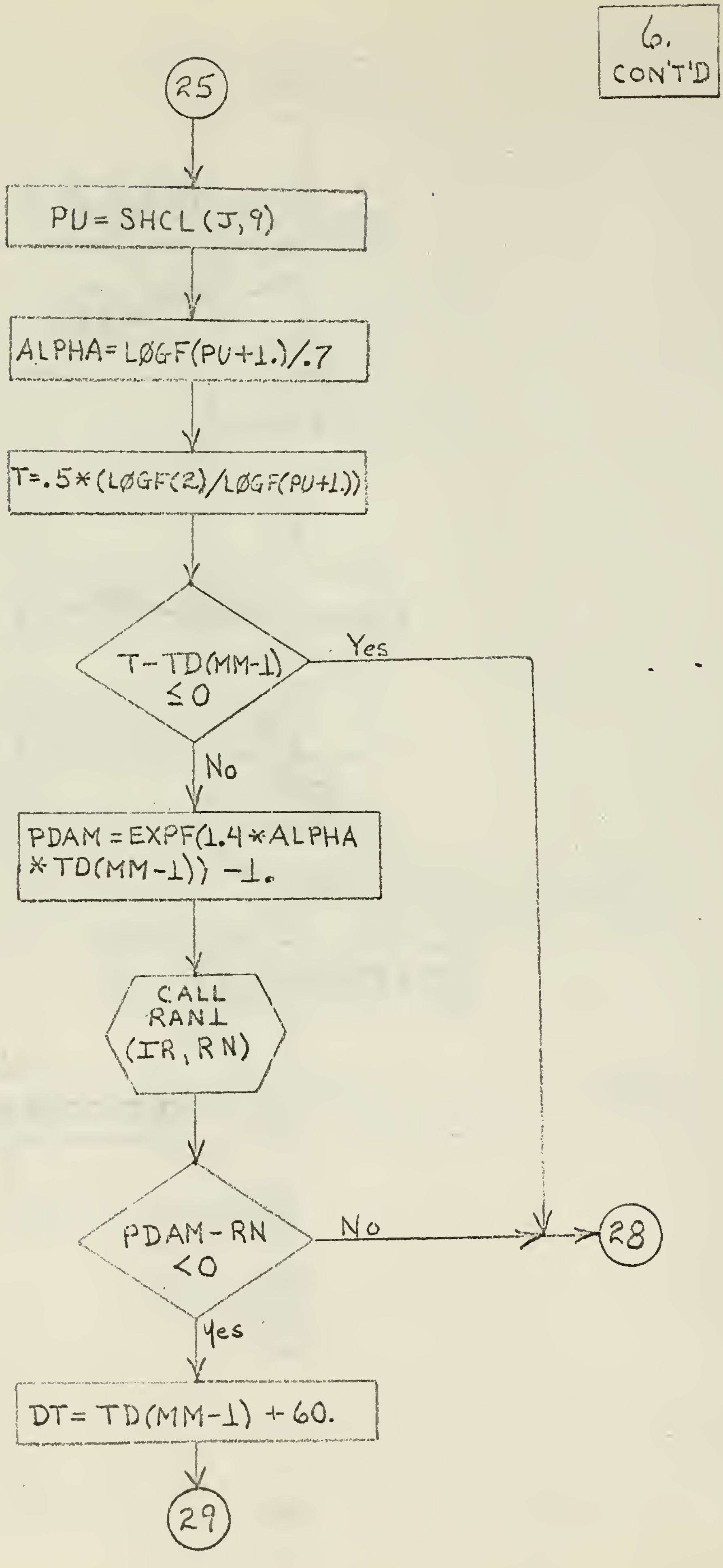
5. CONT'D

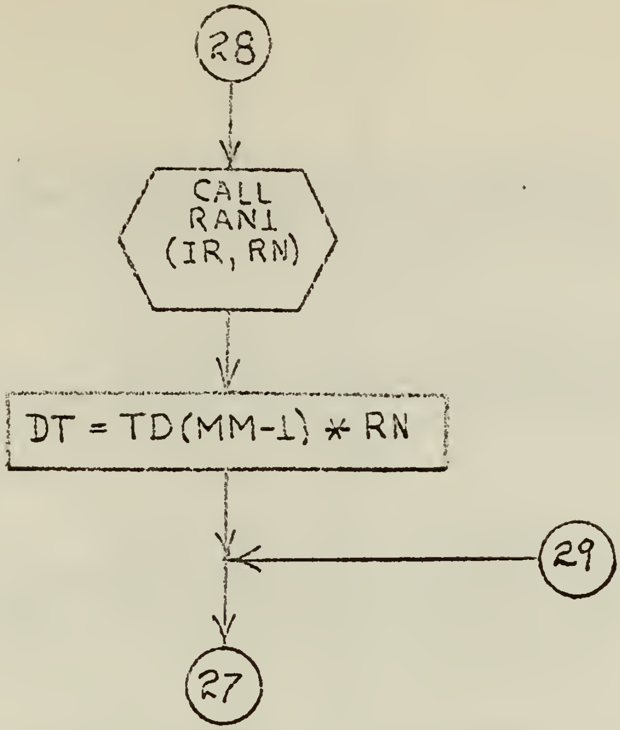

22
TE=(SQRTF(DX+DY))/S
TD(MM)=TE+TD(MM-1)
MM=MM+1
TPX=XLDL(I1)
TPY=XLDL(I3)
II=N
No
II=II+1
23
Yes
KK=NTØTLG
No
KK=KK+1
24
Yes
CONTINUE

6.



ENTRY
GØ TØ JJ
JJ=2
25
JJ=1
JJ=3
26
CALL RAN1 (IR, RN)
RN- ACCL(J,6) ≤0
Yes
No
CALL RAN1 (IR, RN)
DT = TD(MM-1) * RN
DT=TD(MM-1) +5.
27


6. CON'T'D
25
PU = SHCL(J,9)
ALPHA = LØGF(PU+1.)/.7
T=.5*(LØGF(2)/LØGF(PU+1.))
T-TD(MM-1) ≤ 0
Yes
No
PDAM = EXPF(1.4*ALPHA *TD(MM-1)) -1.
CALL RAN1 (IR, RN)
PDAM-RN <0
No
28
Yes
DT= TD(MM-1) + 60.
29



28
CALL RAN1 (IR, RN)
DT = TD(MM-1) * RN
29
27

6.
CON'T'D

6 CONT'D

26

```
PRØB(1)= (1.0 - SUCL(J,9)) * (1.0 - SUCL(J,11)

PRØB(2)= PRØB(1) + (1.0-SUCL(J,9) *
   SUCL(J,11) * (1.0-SUCL(J,12))

PRØB(3)= PRØB(2) + (1.0-SUCL(J,9)*
SUCL(J,11) * SUCL(J,12) * (1.0-SUCL(J,13))

PRØB(4)= PRØB(3) + (1.0 - SUCL(J,9) *
   SUCL(J,11) * SUCL(J,12) * SUCL(J,13)

PRØB(5)= PRØB(4) + SUCL(J,9) * (1.0 -
SUCL(J,10)) * (1.0 - SUCL(J,15))

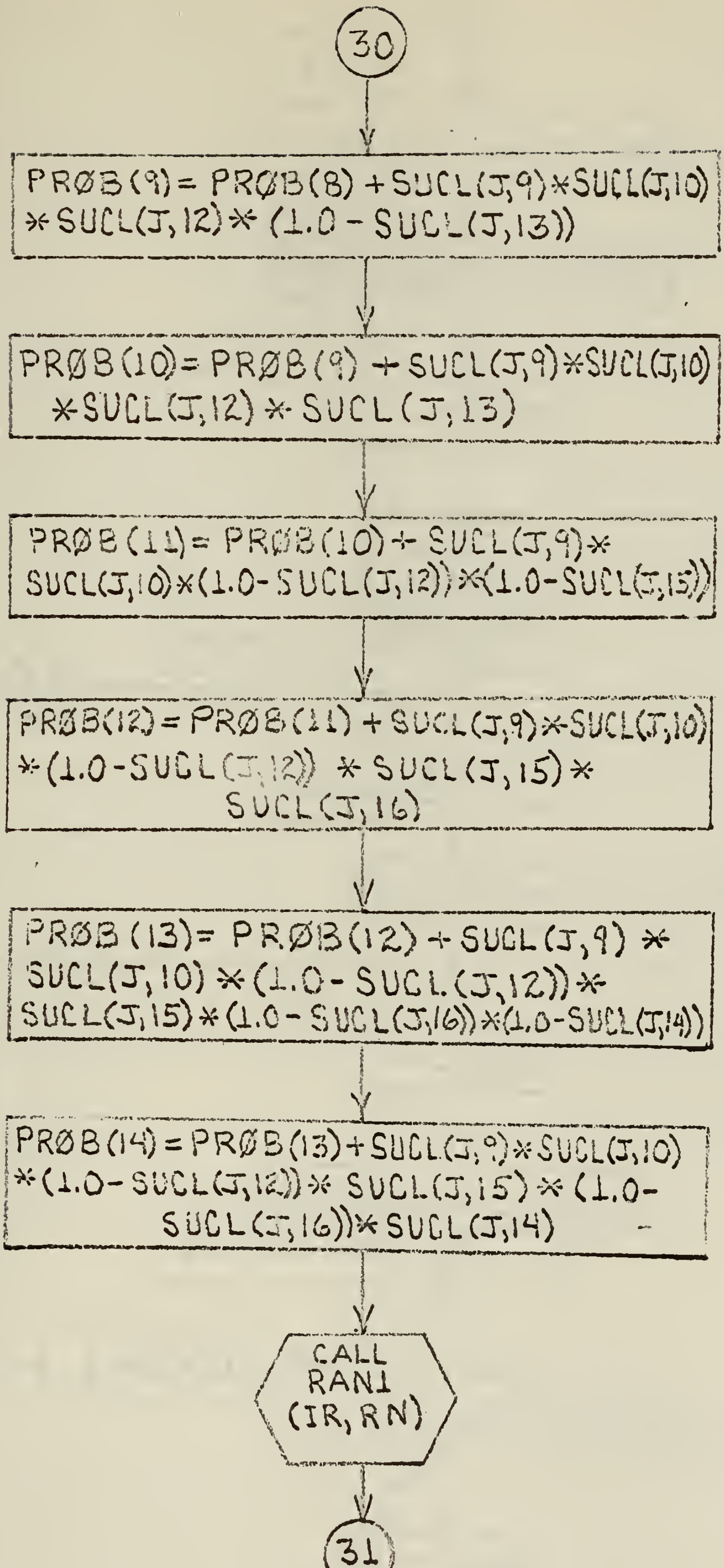
PRØB(6)= PRØB(5) + SUCL(J,9) * (1.0-
SUCL(J,10)) * SUCL(J,15) * (1.0 -
SUCL(J,16)) * (1.0 - SUCL(J,14))

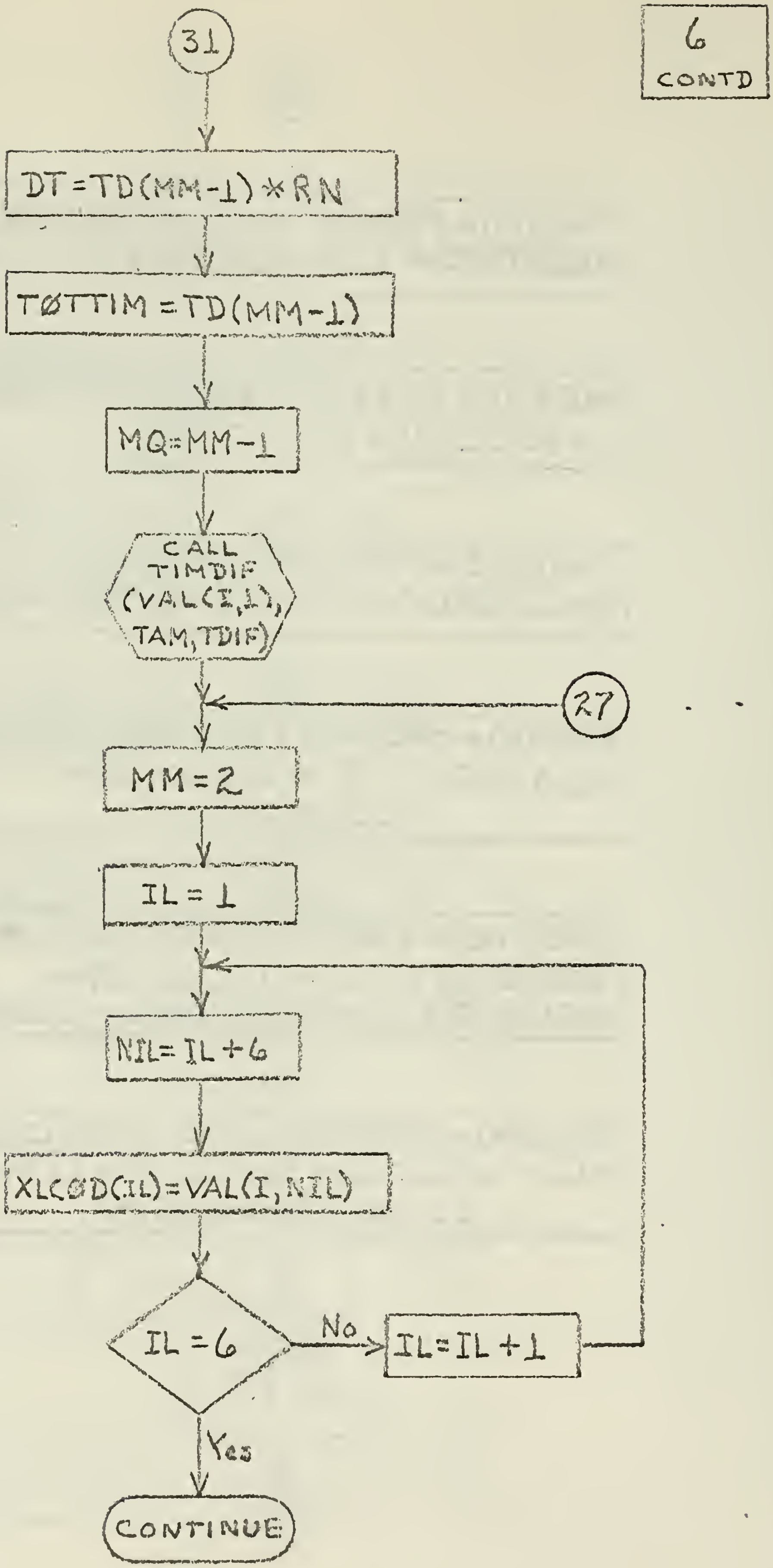
PRØB(7)= PRØB(6) + SUCL(J,9) * (1.0-
SUCL(J,10)) *  SUCL(J,15)  * (1.0-
SUCL(J,16)) * SUCL(J,14)

PRØB(8)= PRØB(7) + SUCL(J,9) * (1.0-
SUCL(J,10)) * SUCL(J,15) * SUCL(J,16)
```

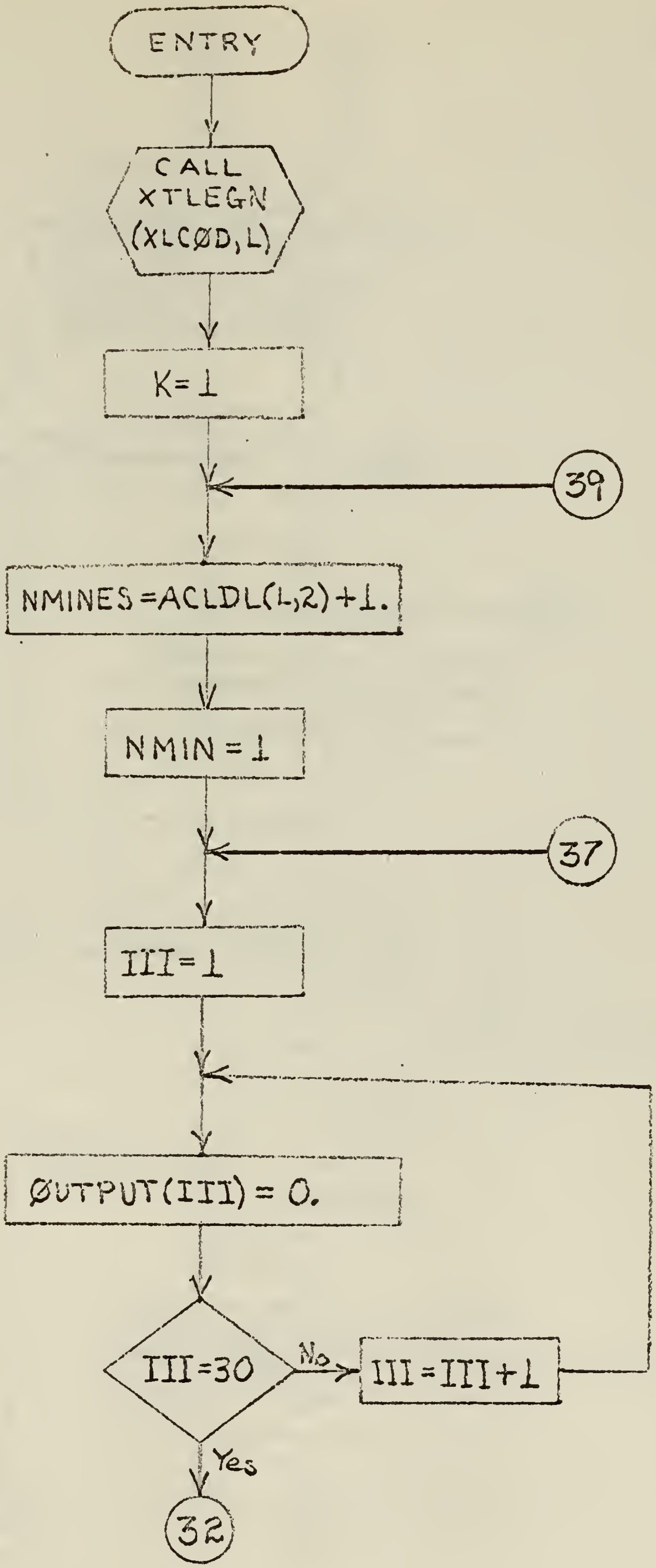
30

6. CONT'D

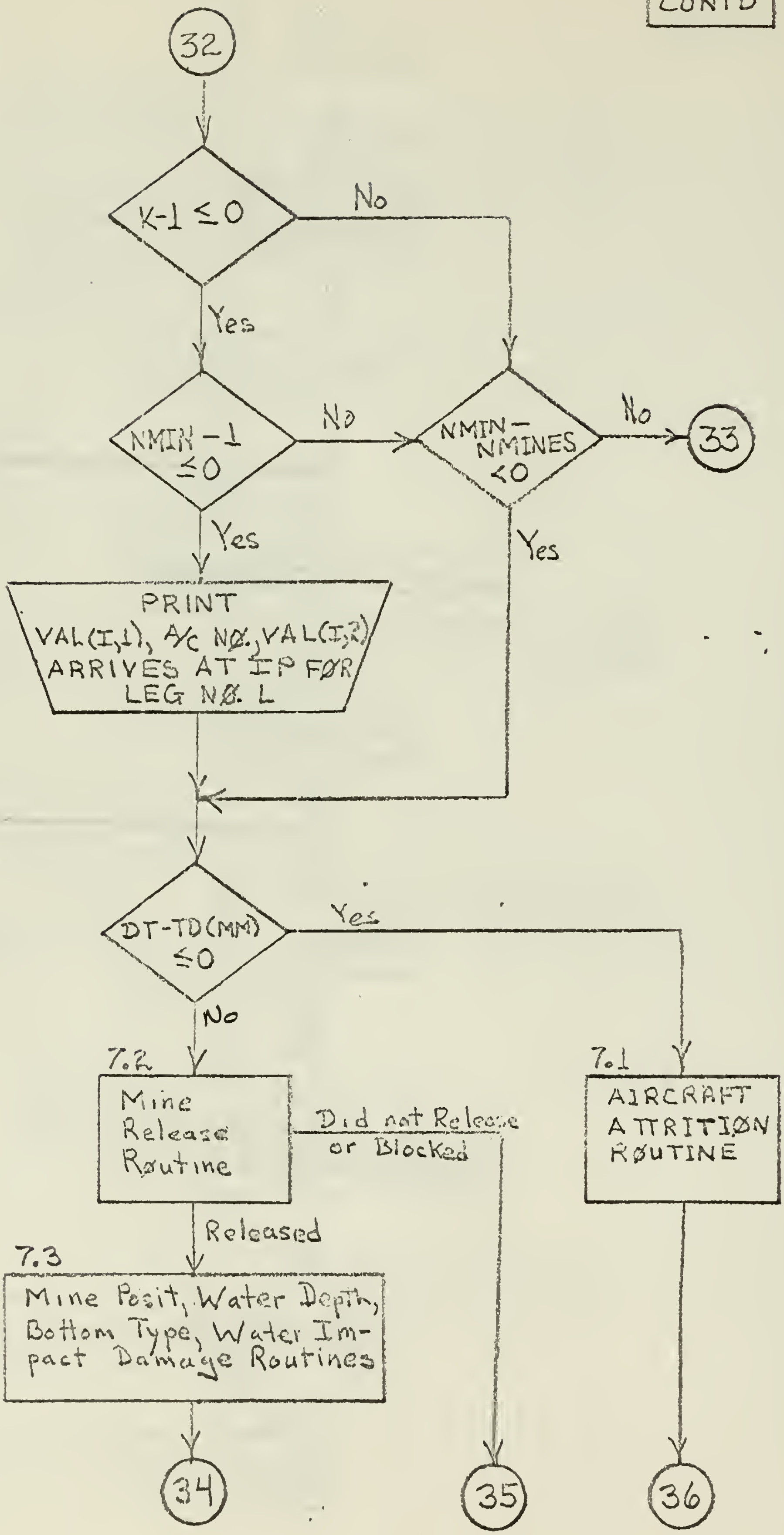

30
PRØB(9) = PRØB(8) + SUCL(J,9)*SUCL(J,10)*SUCL(J,12)*(1.0 - SUCL(J,13))
PRØB(10) = PRØB(9) + SUCL(J,9)*SUCL(J,10)*SUCL(J,12)*SUCL(J,13)
PRØB(11) = PRØB(10) + SUCL(J,9)*SUCL(J,10)*(1.0-SUCL(J,12))*(1.0-SUCL(J,15))
PRØB(12) = PRØB(11) + SUCL(J,9)*SUCL(J,10)*(1.0-SUCL(J,12))*SUCL(J,15)*SUCL(J,16)
PRØB(13) = PRØB(12) + SUCL(J,9)*SUCL(J,10)*(1.0-SUCL(J,12))*SUCL(J,15)*(1.0-SUCL(J,16))*(1.0-SUCL(J,14))
PRØB(14) = PRØB(13) + SUCL(J,9)*SUCL(J,10)*(1.0-SUCL(J,12))*SUCL(J,15)*(1.0-SUCL(J,16))*SUCL(J,14)
CALL RAN1 (IR, RN)
31

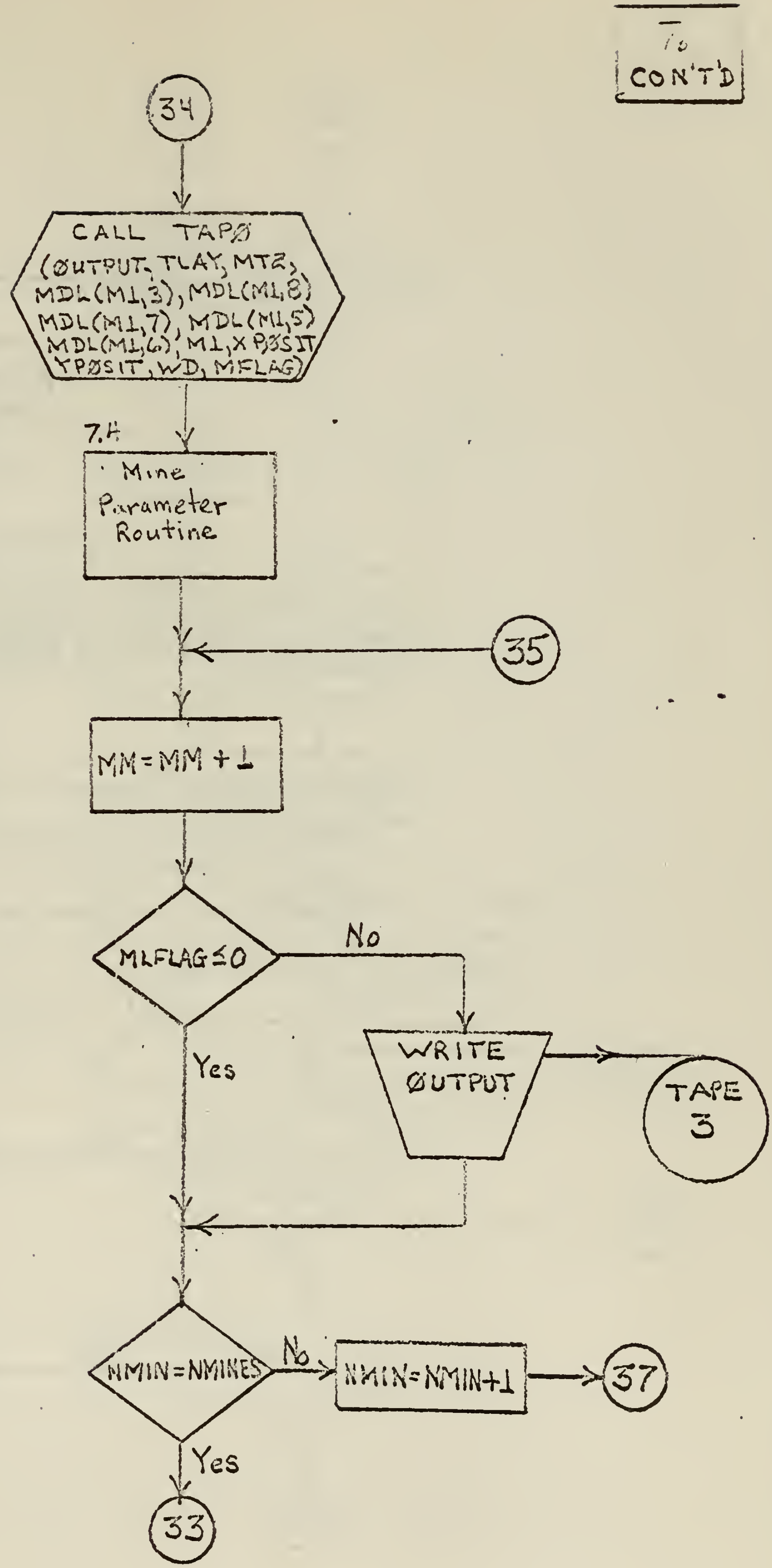

31
6 CONTD
DT=TD(MM-1)*RN
TØTTIM=TD(MM-1)
MQ=MM-1
CALL TIMDIF (VAL(I,1), TAM, TDIF)
27
MM=2
IL=1
NIL=IL+6
XLCØD(IL)=VAL(I,NIL)
IL=6
No
IL=IL+1
Yes
CONTINUE

7.

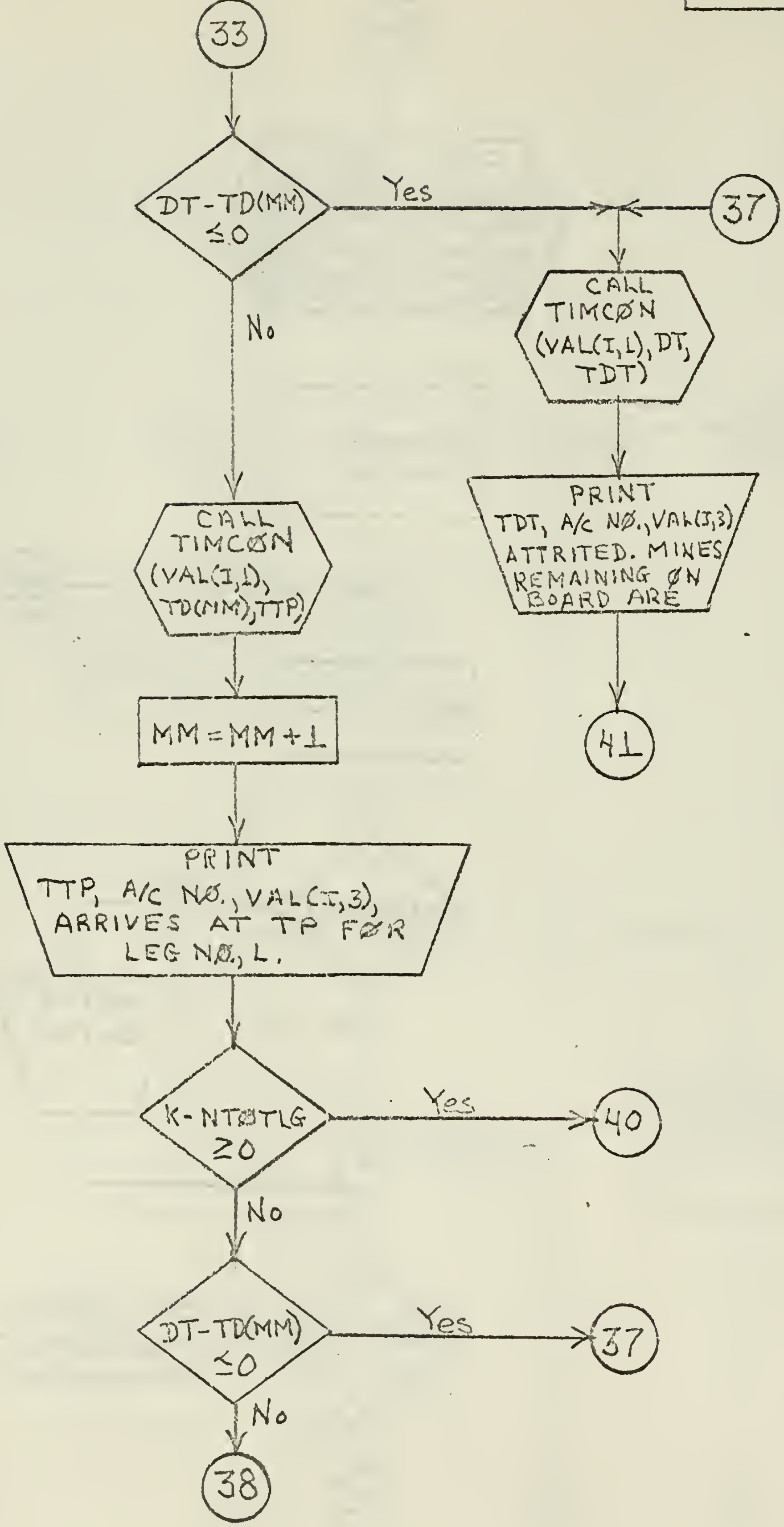

ENTRY
CALL XTLEGN (XLCØD, L)
K = 1
39
NMINES = ACLDL(L,2) + 1.
NMIN = 1
37
III = 1
ØUTPUT(III) = 0.
III = 30
No
III = III + 1
Yes
32

7.
CONTD


32
K-1 ≤ 0
No
Yes
NMIN − 1 ≤ 0
No
NMIN − NMINES <0
No
33
Yes
Yes
PRINT VAL(I,1), A/C NØ., VAL(I,2) ARRIVES AT IP FØR LEG NØ. L
DT-TD(MM) ≤ 0
Yes
No
7.2
Mine Release Røutine
Did not Release or Blocked
7.1
AIRCRAFT ATTRITIØN RØUTINE
Released
7.3
Mine Posit, Water Depth, Bottom Type, Water Impact Damage Routines
34
35
36

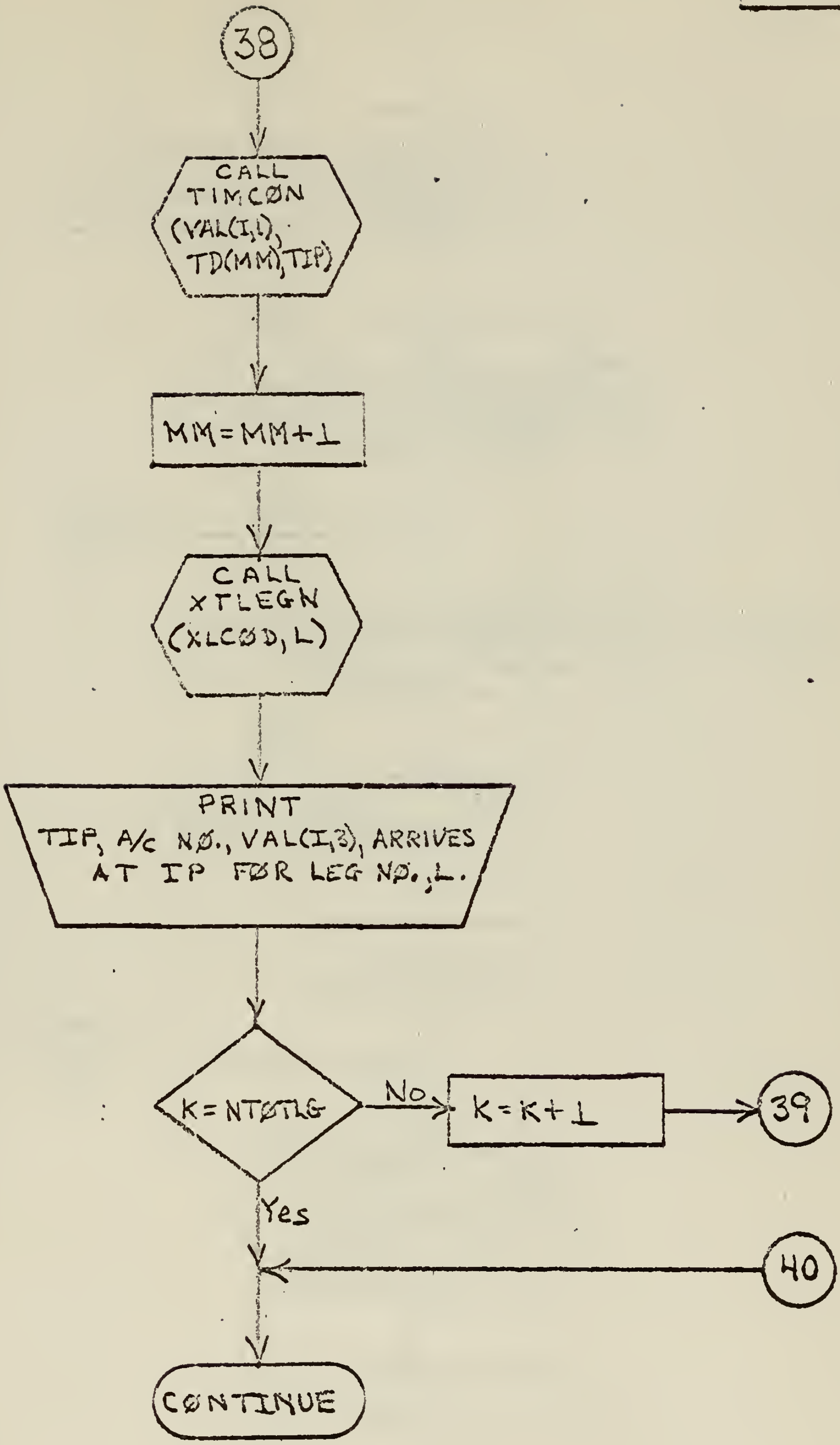

To CON'T'D
34
CALL TAPØ (ØUTPUT, TLAY, MTZ, MDL(M1,3), MDL(M1,8) MDL(M1,7), MDL(M1,5) MDL(M1,6), M1, XPØSIT YPØSIT, WD, MFLAG)
7.4
Mine Parameter Routine
35
MM=MM+1
M1FLAG≤0
No
Yes
WRITE ØUTPUT
TAPE 3
NMIN=NMINES
No
NMIN=NMIN+1
37
Yes
33

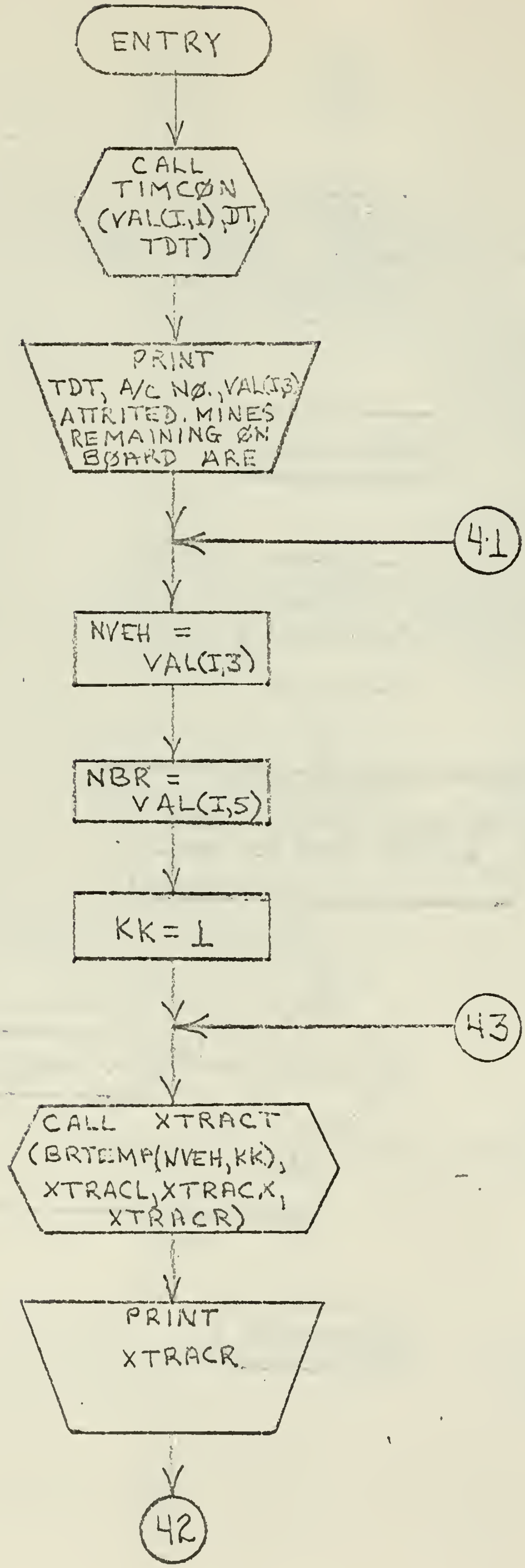
7.
CON'T'D



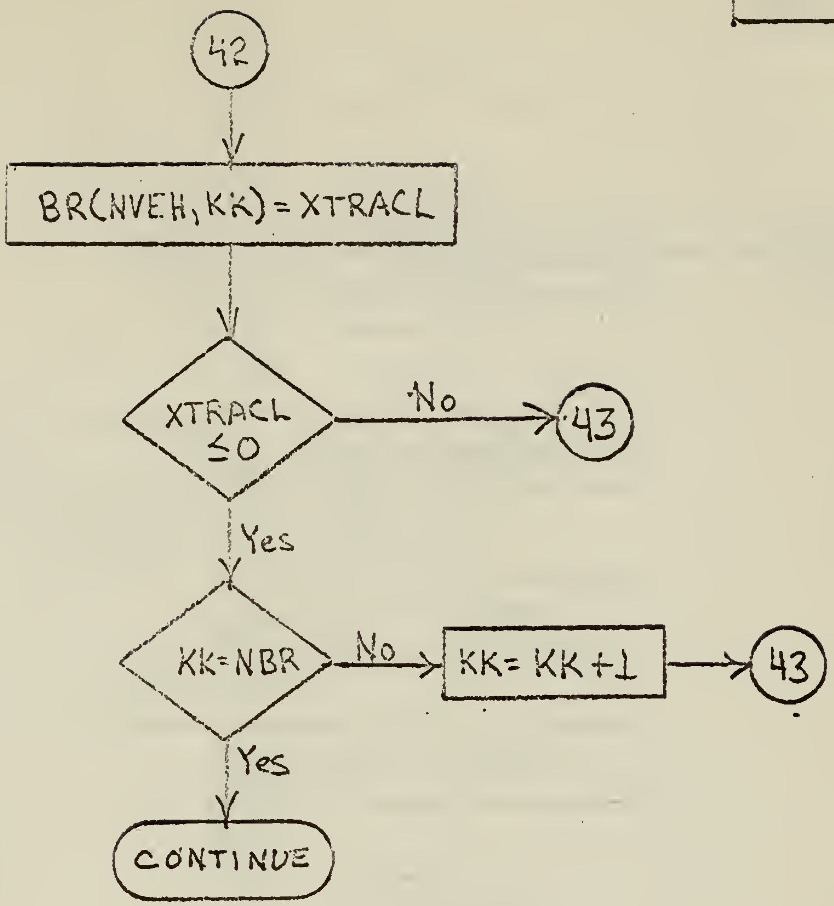
33
DT-TD(MM) ≤0
Yes
37
No
CALL TIMCØN (VAL(I,1),DT, TDT)
PRINT TDT, A/C NØ.,VAL(I,3) ATTRITED. MINES REMAINING ØN BOARD ARE
41
CALL TIMCØN (VAL(I,1), TD(MM),TTP)
MM=MM+1
PRINT TTP, A/C NØ., VAL(I,3), ARRIVES AT TP FØR LEG NØ., L.
K-NTØTLG ≥0
Yes
40
No
DT-TD(MM) ≤0
Yes
37
No
38

7.
CON'T'D

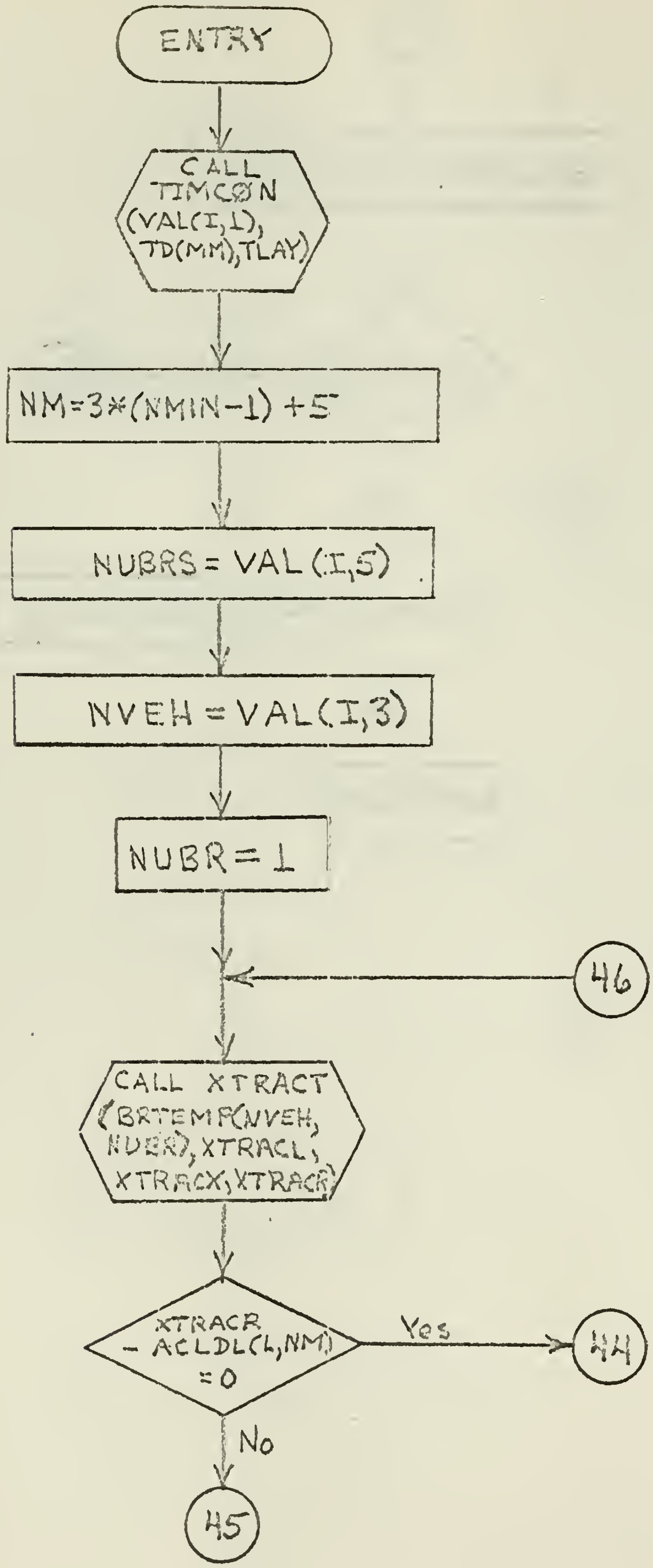

38
CALL
TIMCØN
(VAL(I,1),
TD(MM),TIP)
MM=MM+1
CALL
XTLEGN
(XLCØD,L)
PRINT
TIP, A/C NØ., VAL(I,3), ARRIVES
AT IP FØR LEG NØ.,L.
K=NTØTLG
No
K=K+1
39
Yes
40
CØNTINUE

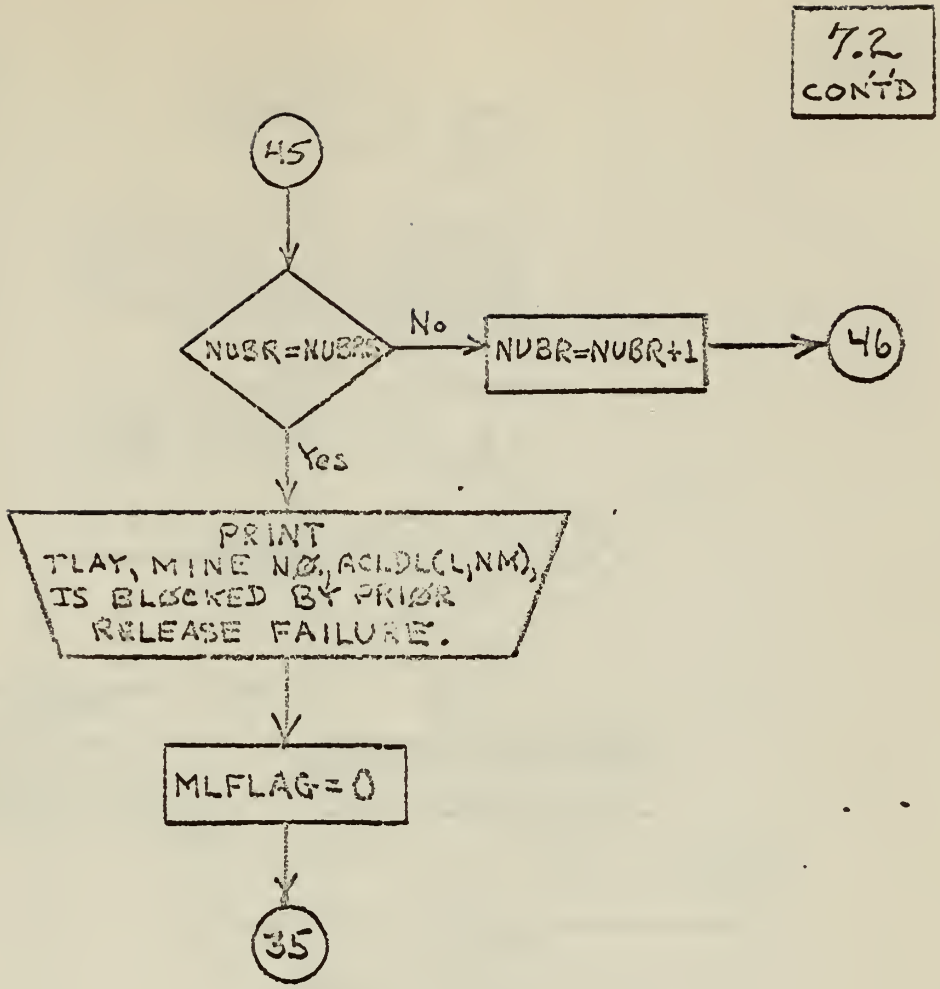


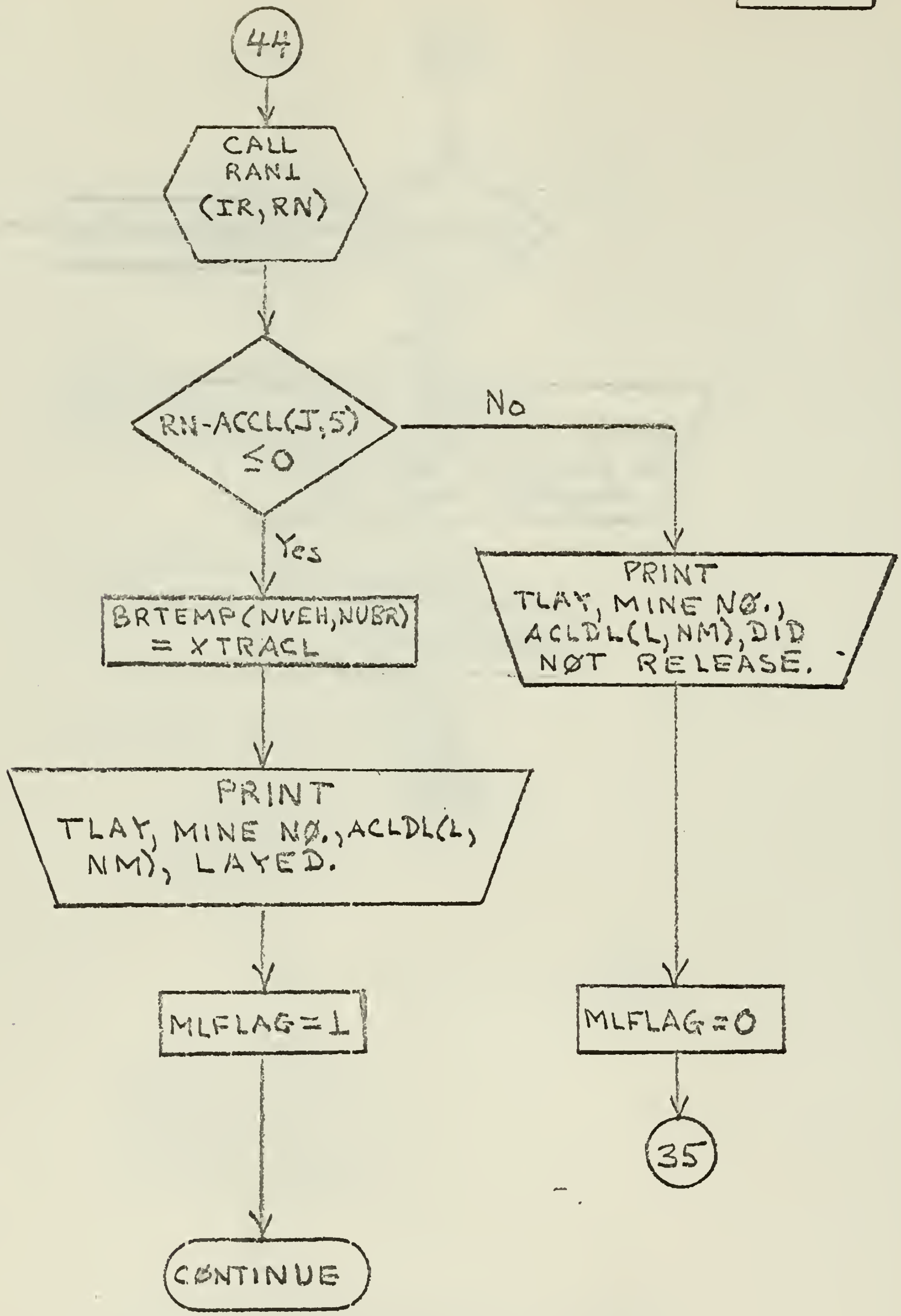
ENTRY
CALL TIMCØN (VAL(I,1),DT, TDT)
PRINT TDT, A/C NØ., VAL(I,3) ATTRITED. MINES REMAINING ØN BØARD ARE
41
NVEH = VAL(I,3)
NBR = VAL(I,5)
KK = 1
43
CALL XTRACT (BRTEMP(NVEH,KK), XTRACL,XTRACX, XTRACR)
PRINT XTRACR
42


42
BR(NVEH,KK) = XTRACL
XTRACL ≤0
No
43
Yes
KK=NBR
No
KK= KK+1
43
Yes
CONTINUE

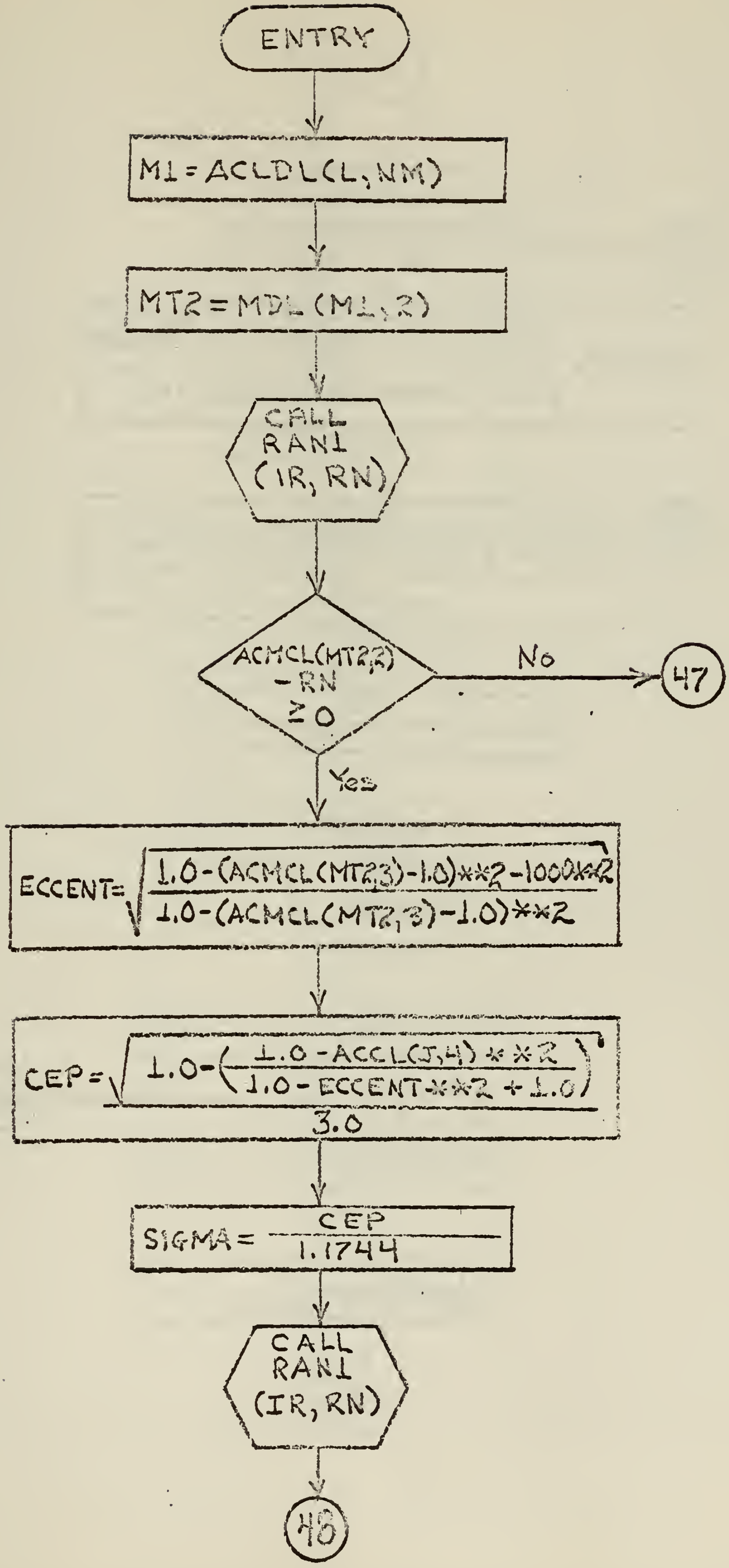
7.2


ENTRY
CALL TIMCØN (VAL(I,1), TD(MM),TLAY)
NM=3*(NMIN-1)+5
NUBRS = VAL(I,5)
NVEH = VAL(I,3)
NUBR = 1
46
CALL XTRACT (BRTEMP(NVEH, NUBR), XTRACL, XTRACX, XTRACR)
XTRACR - ACLDL(L,NM) = 0
Yes
44
No
45

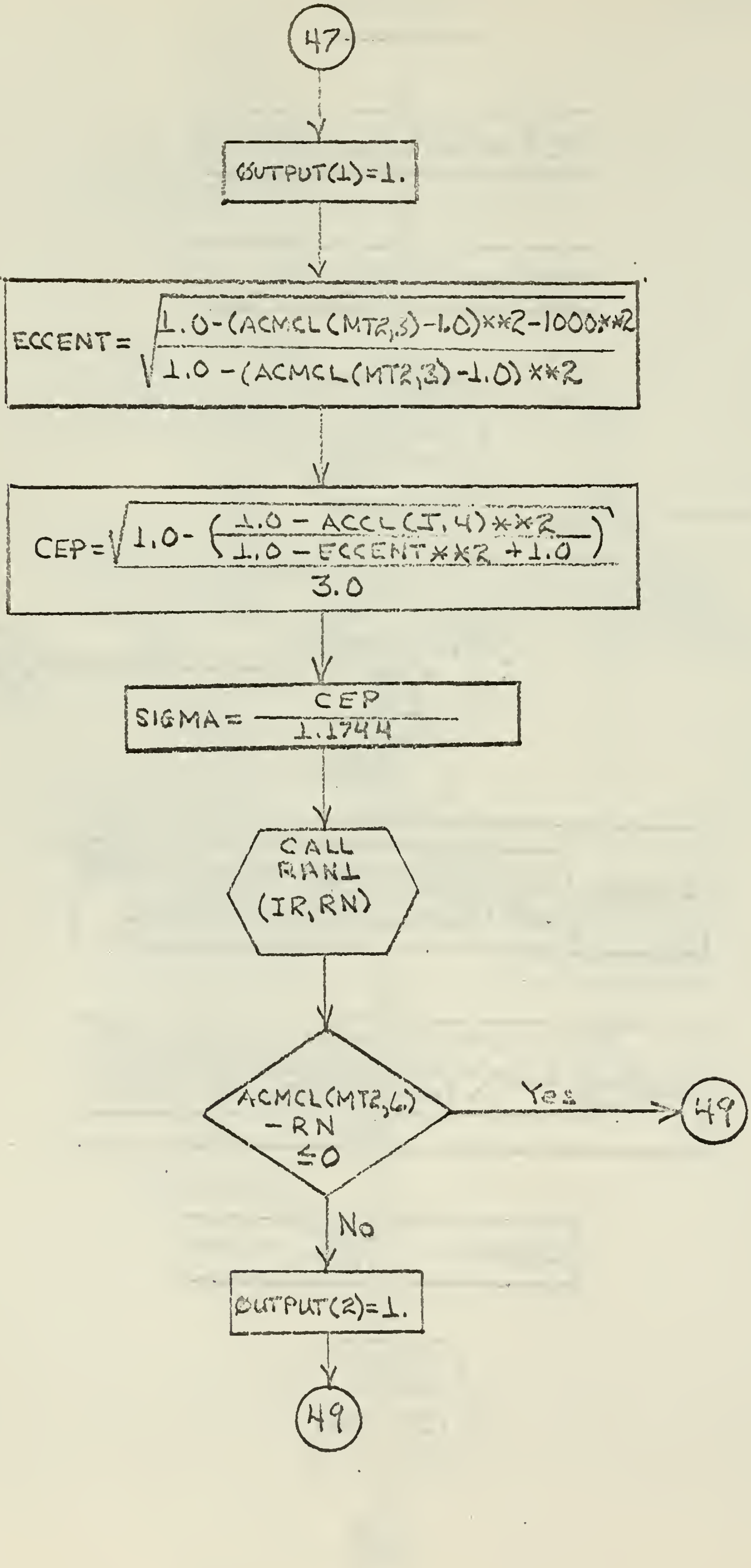

7.2 CONT'D
45
NUBR=NUBRS
No
NUBR=NUBR+1
46
Yes
PRINT
TLAY, MINE NØ, ACLDL(L,NM),
IS BLØCKED BY PRIØR
RELEASE FAILURE.
MLFLAG=0
35


44
CALL
RAN1
(IR, RN)
RN-ACCL(J,5)
≤0
No
Yes
BRTEMP(NVEH,NUBR)
= XTRACL
PRINT
TLAY, MINE NØ., ACLDL(L, NM), LAYED.
MLFLAG=1
CØNTINUE
PRINT
TLAY, MINE NØ.,
ACLDL(L, NM), DID
NØT RELEASE.
MLFLAG=0
35

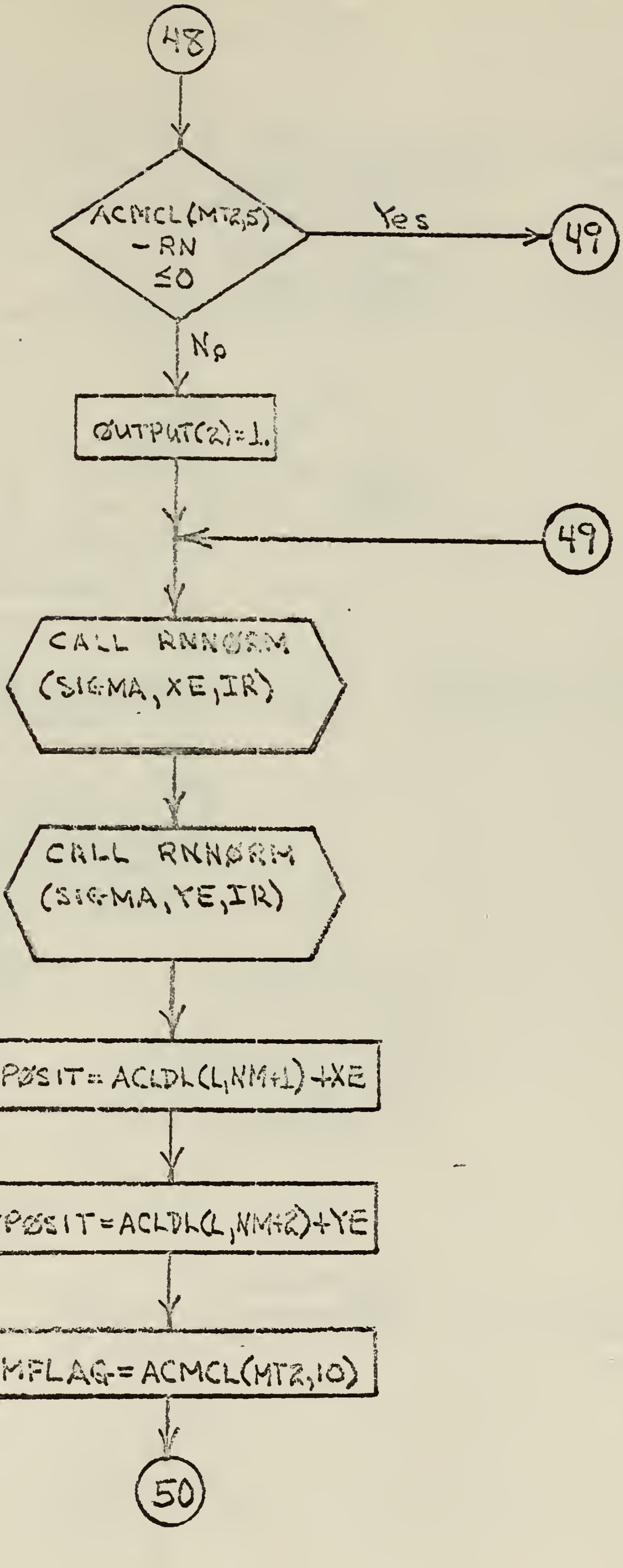
7.3


ENTRY
M1 = ACLDL(L, NM)
MT2 = MDL (M1, 2)
CALL RAN1 (IR, RN)
ACMCL(MT2,2) - RN ≥ 0
No
47
Yes
ECCENT = $\sqrt{\frac{1.0-(ACMCL(MT2,3)-1.0)**2-1000**2}{1.0-(ACMCL(MT2,3)-1.0)**2}}$
CEP = $\frac{\sqrt{1.0-\left(\frac{1.0-ACCL(J,4)**2}{1.0-ECCENT**2+1.0}\right)}}{3.0}$
SIGMA = $\frac{CEP}{1.1744}$
CALL RAN1 (IR, RN)
48

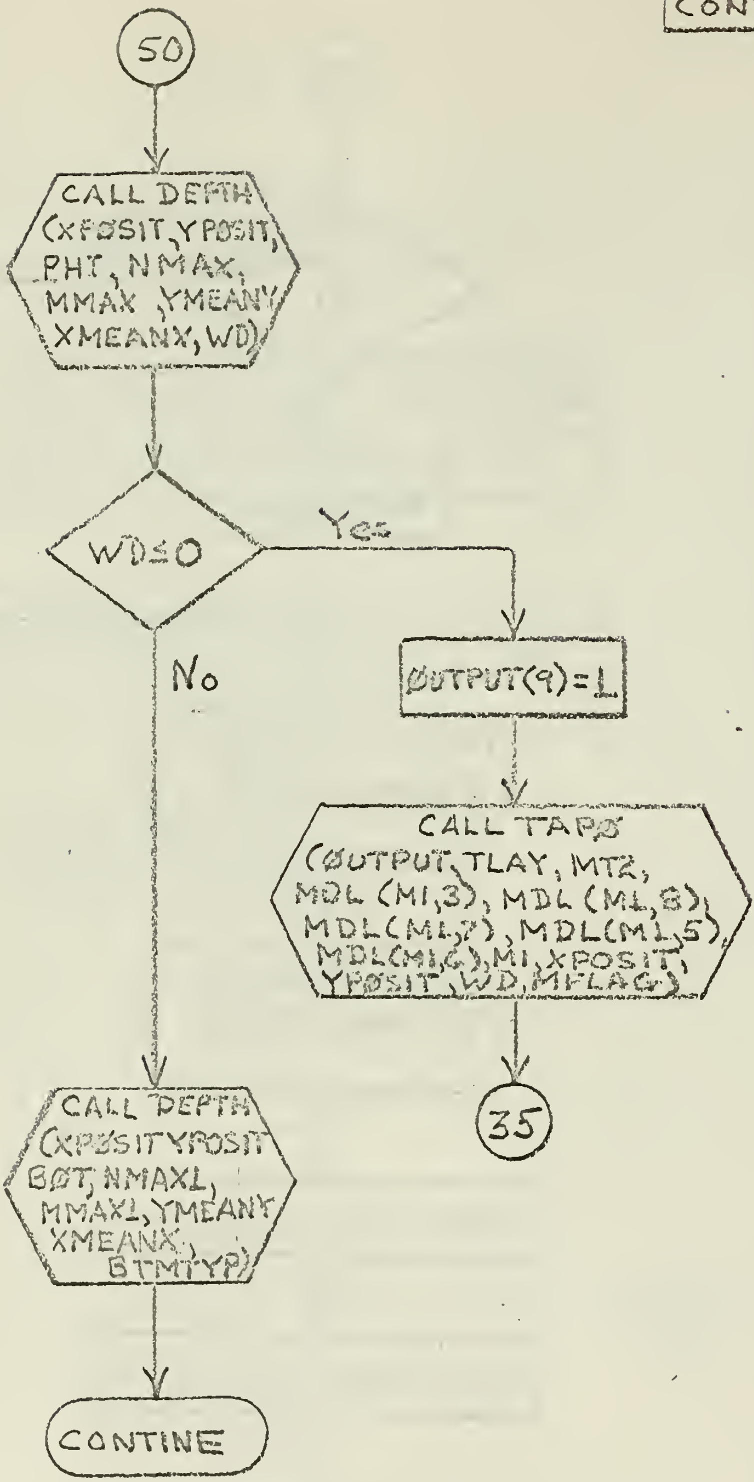
7.3
CONTD

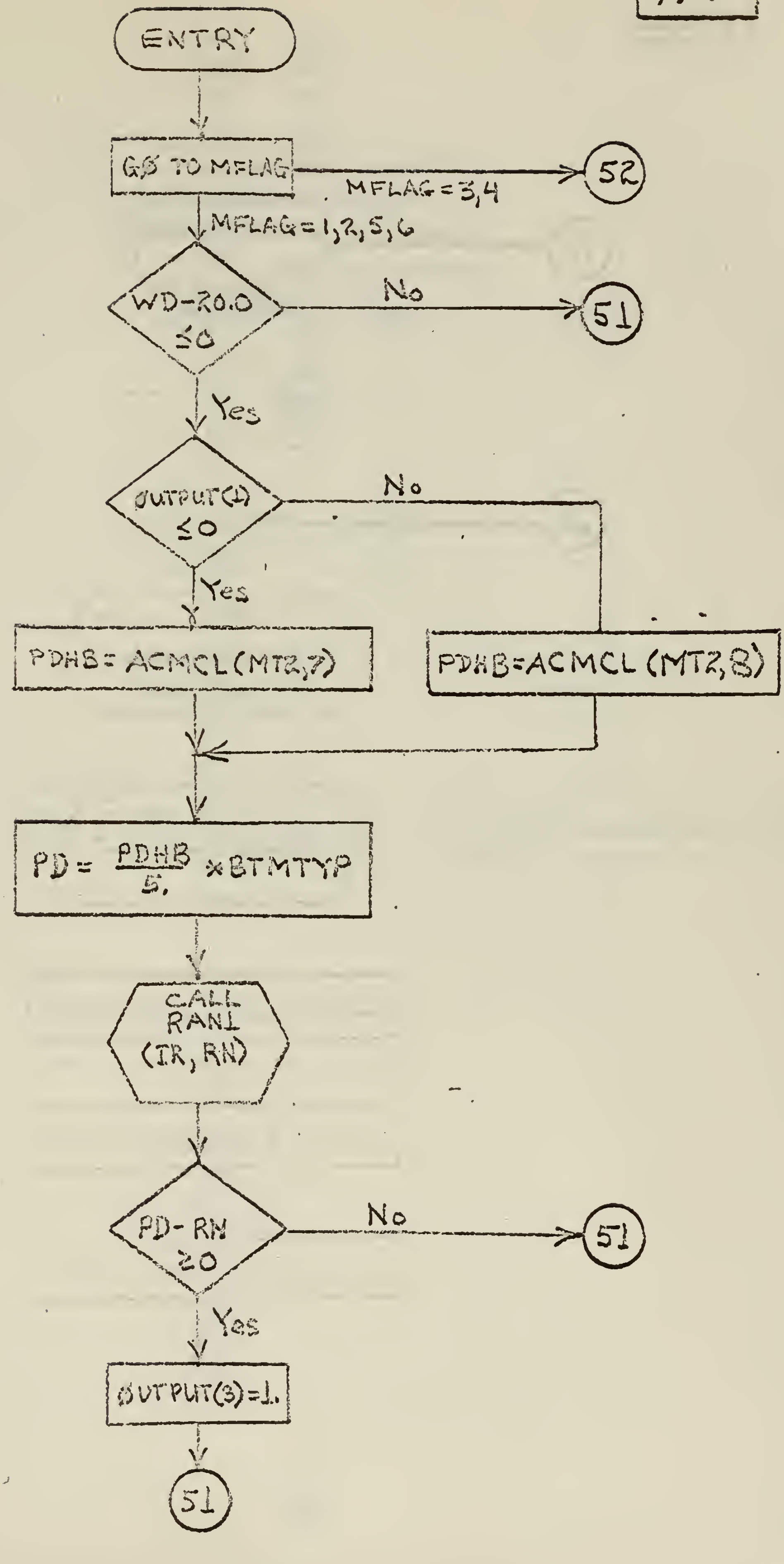

47
OUTPUT(1)=1.
ECCENT = SQRT((1.0-(ACMCL(MT2,3)-1.0)**2-1000**2) / (1.0-(ACMCL(MT2,3)-1.0)**2))
CEP = SQRT((1.0-((1.0-ACCL(J,4)**2) / (1.0-ECCENT**2+1.0))) / 3.0)
SIGMA = CEP / 1.1744
CALL
RAN1
(IR,RN)
ACMCL(MT2,6)
-RN
≤0
Yes
49
No
OUTPUT(2)=1.
49

7.3
CONT'D

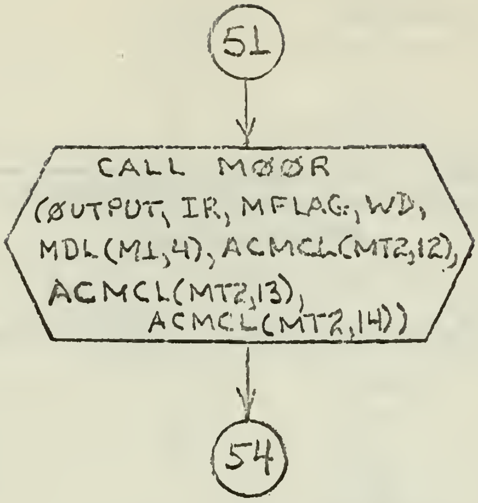

48
ACMCL(MT2,5)
-RN
≤0
Yes
49
No
ØUTPUT(2)=1.
49
CALL RNNØRM
(SIGMA, XE, IR)
CALL RNNØRM
(SIGMA, YE, IR)
XPØSIT= ACLDL(L,NM+1)+XE
YPØSIT=ACLDL(L,NM+2)+YE
MFLAG=ACMCL(MT2,10)
50

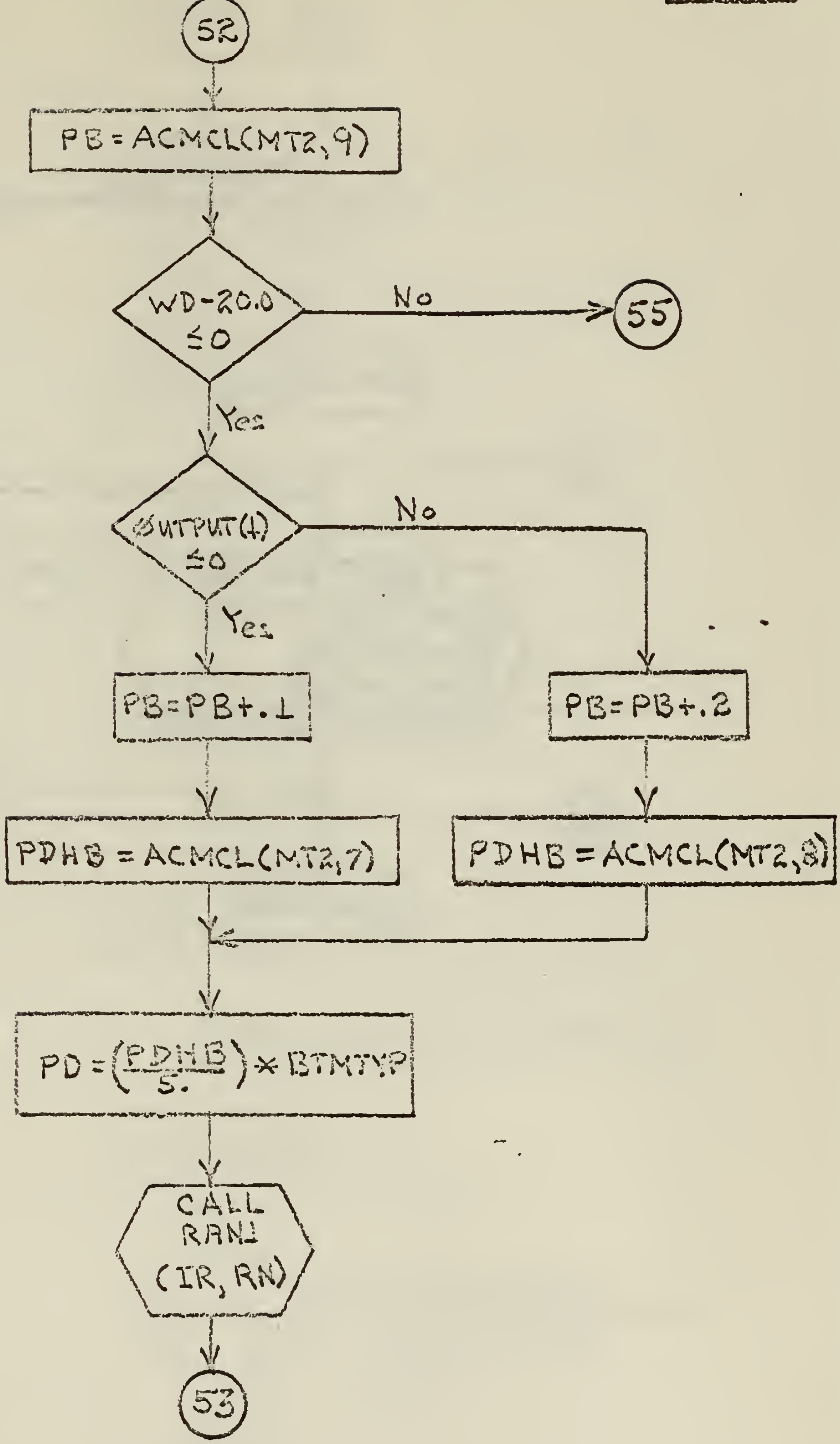
7.3 CONTD

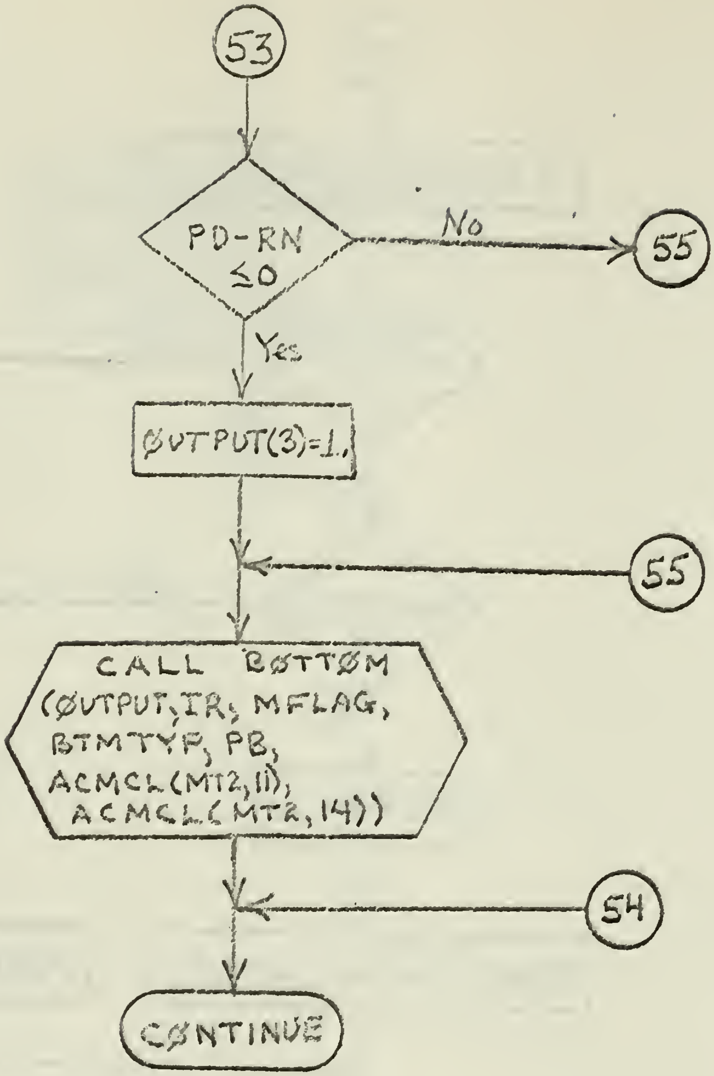

50
CALL DEPTH (XPØSIT, YPØSIT, PHT, NMAX, MMAX, YMEANY, XMEANX, WD)
WD≤0
Yes
No
ØUTPUT(9)=1
CALL TAPØ (ØUTPUT, TLAY, MT2, MDL (M1,3), MDL (M1,8), MDL(M1,7), MDL(M1,5), MDL(M1,6), M1, XPOSIT, YPØSIT, WD, MFLAG)
35
CALL DEPTH (XPØSIT YPØSIT BØT, NMAX1, MMAX1, YMEANY XMEANX, BTMTYP)
CONTINE

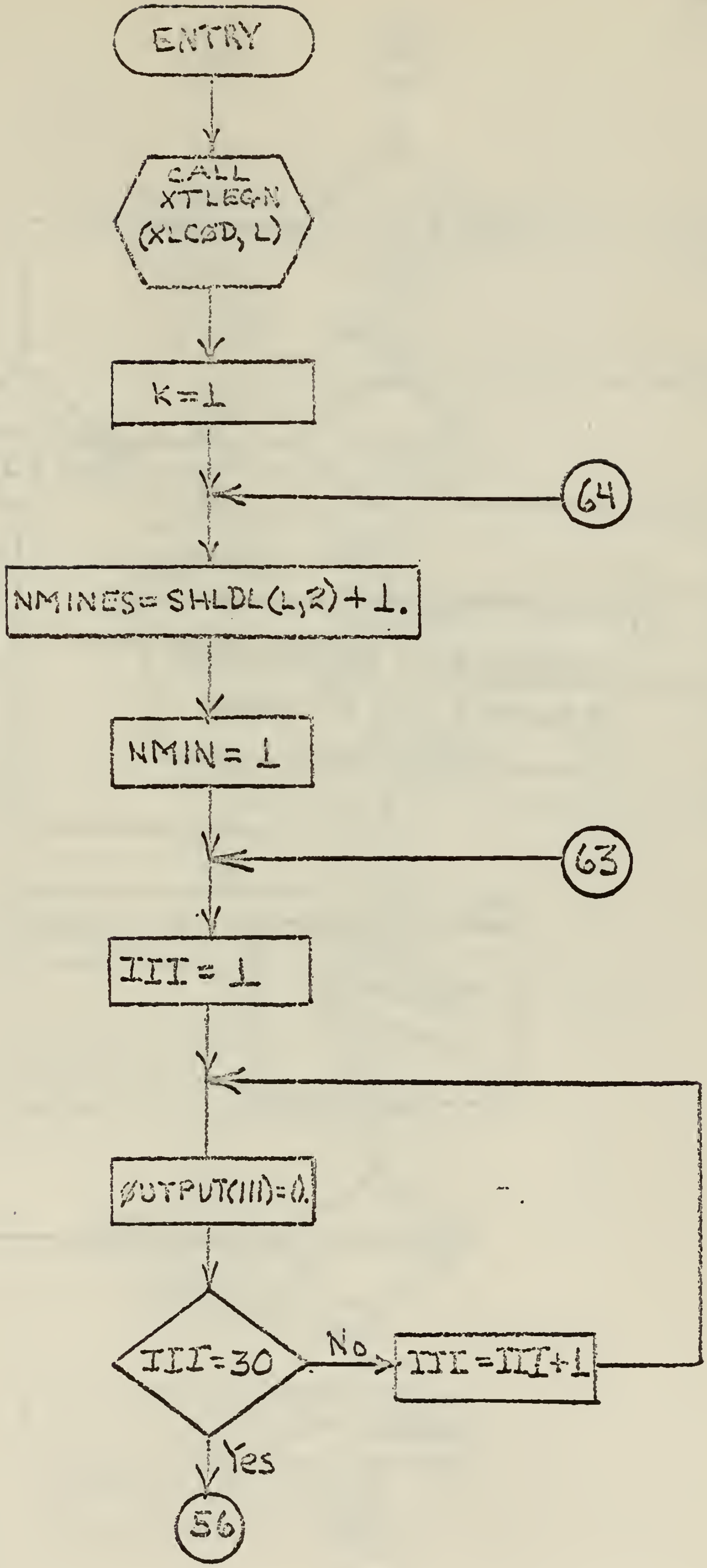

ENTRY
GØ TO MFLAG
MFLAG=3,4
52
MFLAG=1,2,5,6
WD-20.0 ≤0
No
51
Yes
ØUTPUT(1) ≤0
No
Yes
PDHB=ACMCL(MT2,7)
PDHB=ACMCL(MT2,8)
PD= PDHB/5. *BTMTYP
CALL RAN1 (IR, RN)
PD-RN ≥0
No
51
Yes
ØUTPUT(3)=1.
51

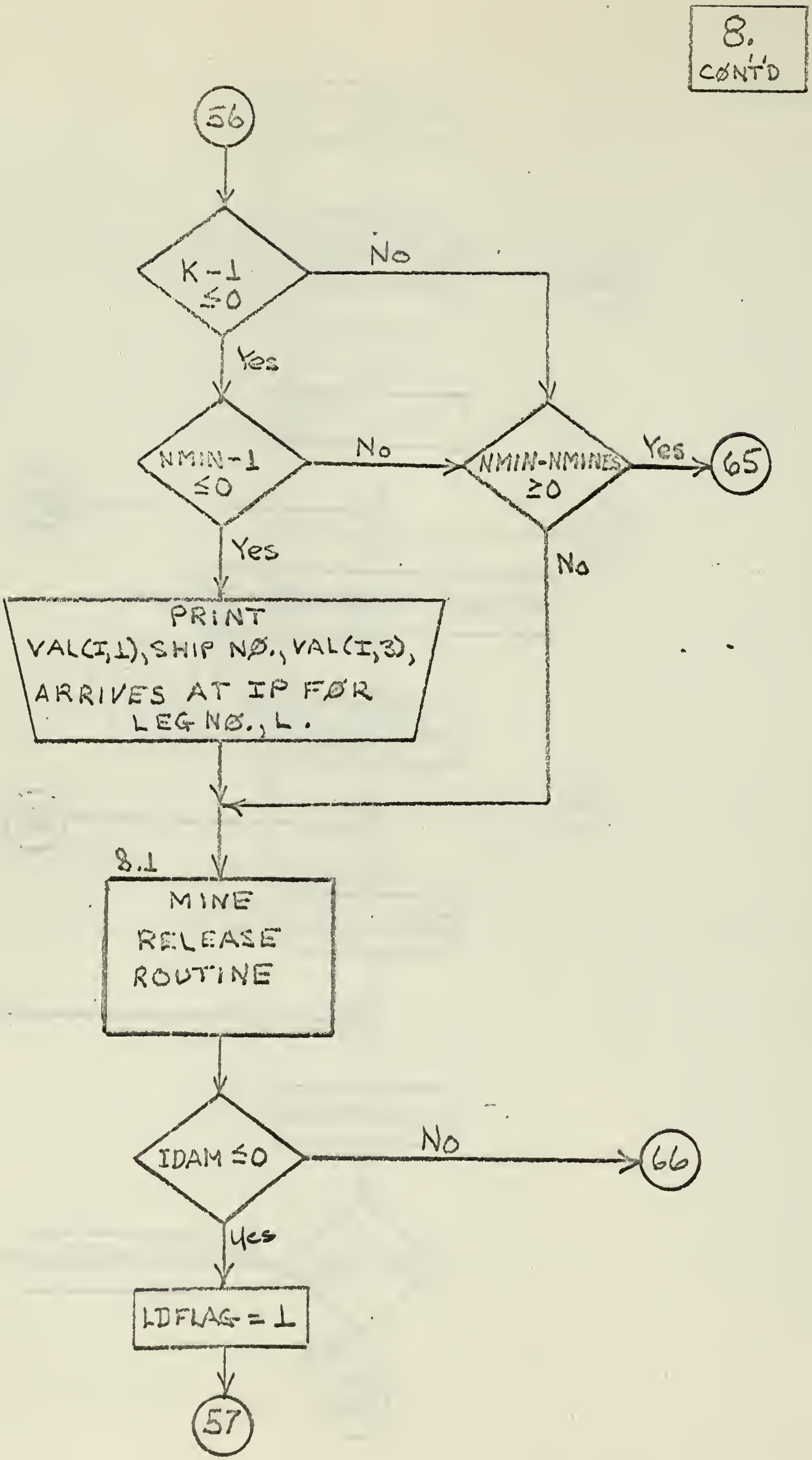
7.4 CONTD


51
CALL MØØR
(ØUTPUT, IR, MFLAG, WD,
MDL(M1,4), ACMCL(MT2,12),
ACMCL(MT2,13),
ACMCL(MT2,14))
54

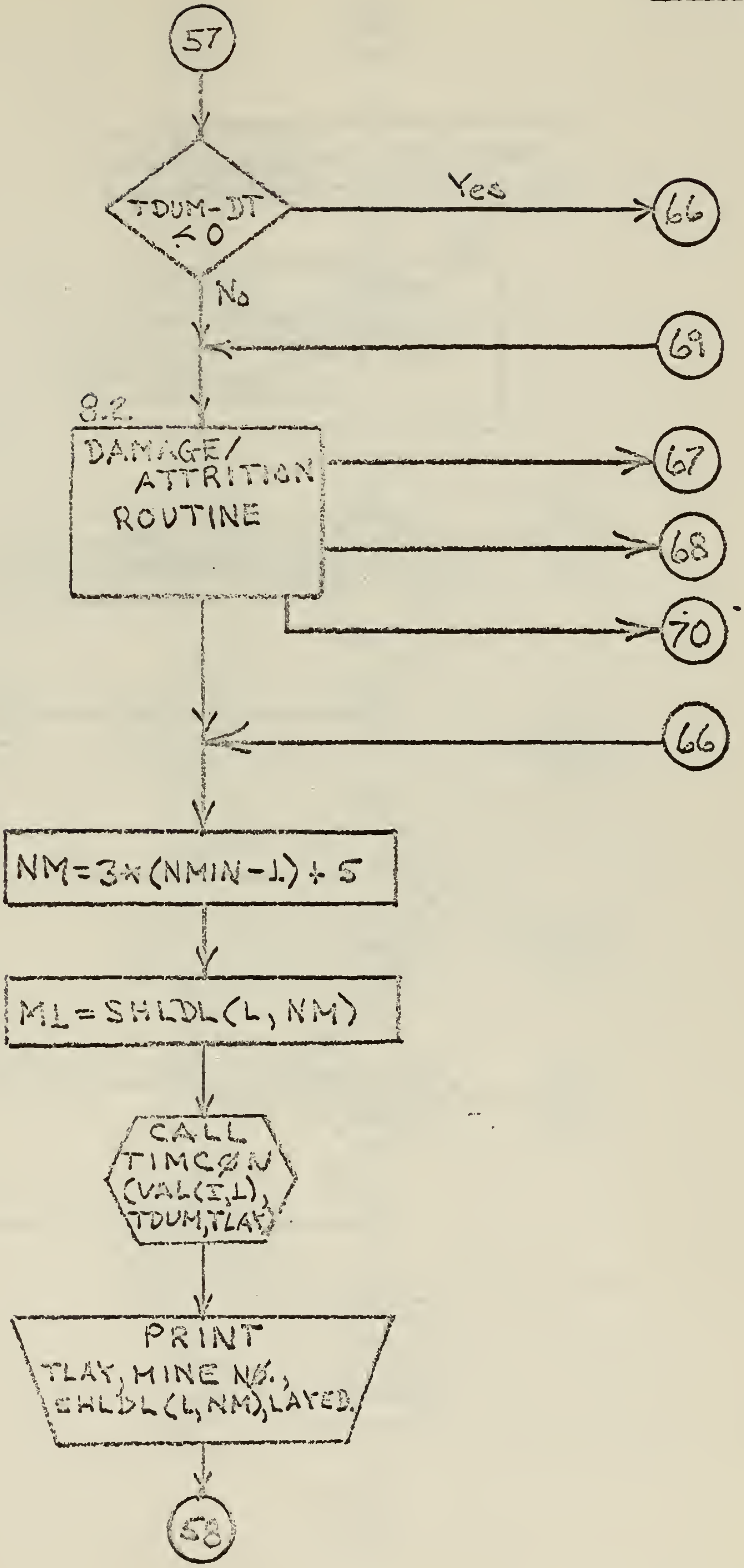

52
PB = ACMCL(MT2, 9)
WD-20.0
≤0
No
55
Yes
ØUTPUT(4)
≤0
No
Yes
PB=PB+.1
PB=PB+.2
PDHB = ACMCL(MT2,7)
PDHB = ACMCL(MT2,8)
PD = (PDHB / 5.) * BTMTYP
CALL
RAN1
(IR, RN)
53


53
PD-RN
≤0
No
55
Yes
ØUTPUT(3)=1.
55
CALL BØTTØM
(ØUTPUT,IR, MFLAG,
BTMTYP, PB,
ACMCL(MT2,11),
ACMCL(MT2,14))
54
CØNTINUE

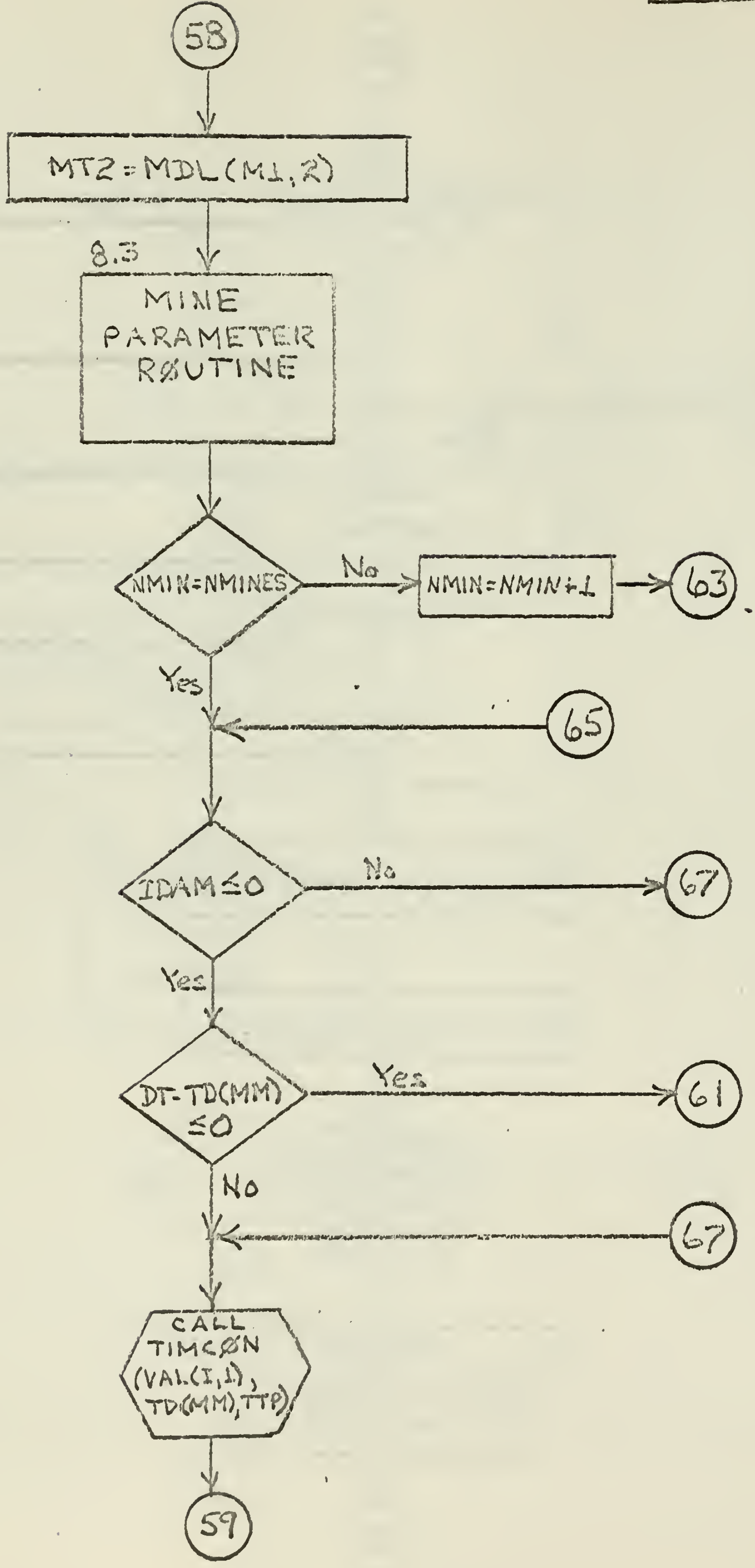

ENTRY
CALL XTLEGN (XLCØD, L)
K=1
64
NMINES=SHLDL(L,2)+1.
NMIN=1
63
III=1
ØUTPUT(III)=0.
III=30
No
III=III+1
Yes
56


8.
CØNT'D
56
K-1
≤0
No
Yes
NMIN-1
≤0
No
NMIN-NMINES
≥0
Yes
65
Yes
No
PRINT
VAL(I,1), SHIP NØ., VAL(I,3),
ARRIVES AT IP FØR
LEG NØ., L.
8.1
MINE
RELEASE
ROUTINE
IDAM ≤0
No
66
Yes
LDFLAG = 1
57

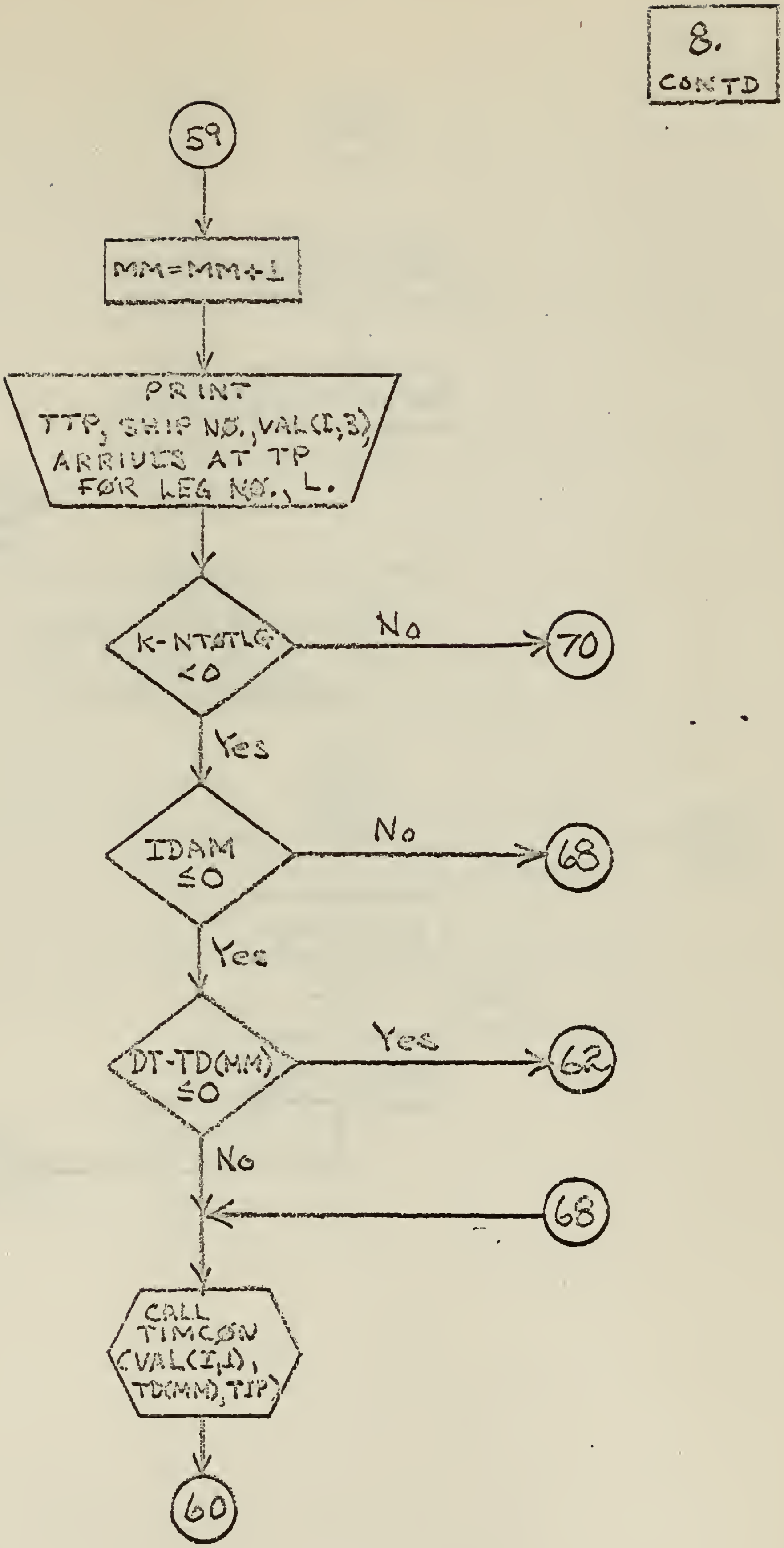
8. CONTD


57
TDUM-DT
≤ 0
Yes
66
No
69
8.2.
DAMAGE/
ATTRITION
ROUTINE
67
68
70
66
NM=3*(NMIN-1)+5
ML=SHLDL(L,NM)
CALL
TIMCØN
(VAL(I,L),
TDUM,TLAY)
PRINT
TLAY, MINE NØ.,
SHLDL(L,NM),LAYED.
58

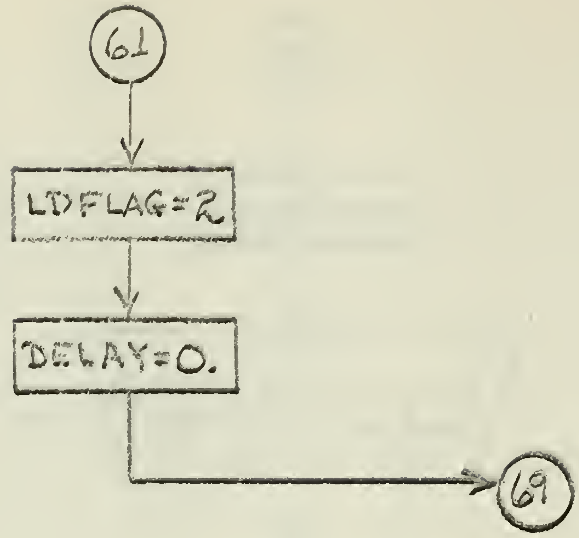
8 CONTD

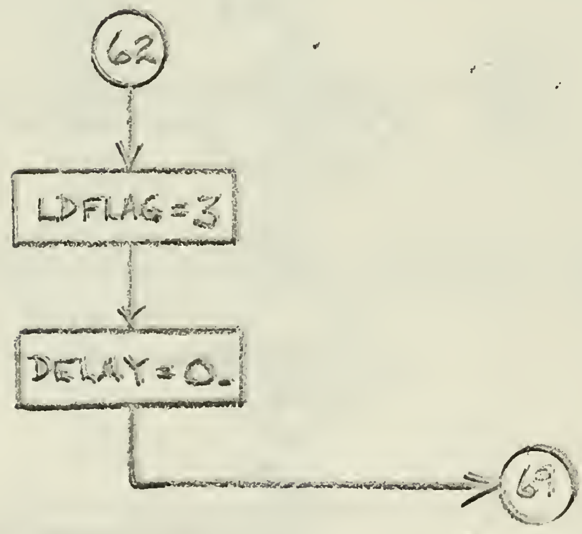


58
MT2 = MDL(M1, 2)
8.3
MINE PARAMETER RØUTINE
NMIN=NMINES
No
NMIN=NMIN+1
63
Yes
65
IDAM≤0
No
67
Yes
DT-TD(MM) ≤0
Yes
61
No
67
CALL TIMCØN (VAL(I,1), TD(MM), TTP)
59

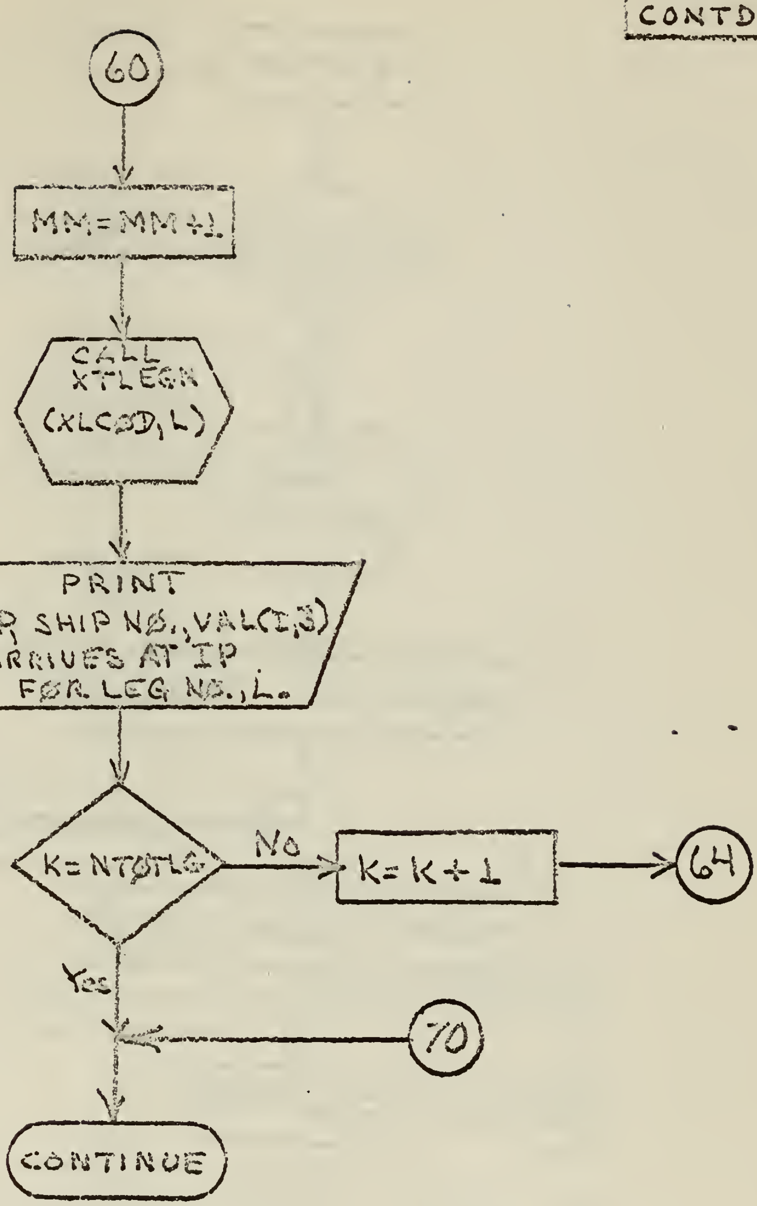

8. CONTD
59
MM=MM+1
PRINT
TTP, SHIP NØ., VAL(I,3), ARRIVES AT TP
FØR LEG NØ., L.
K-NTØTLG
<0
No
70
Yes
IDAM
≤0
No
68
Yes
DT-TD(MM)
≤0
Yes
62
No
68
CALL
TIMCØN
(VAL(I,1),
TD(MM), TIP)
60

8.
CONTD



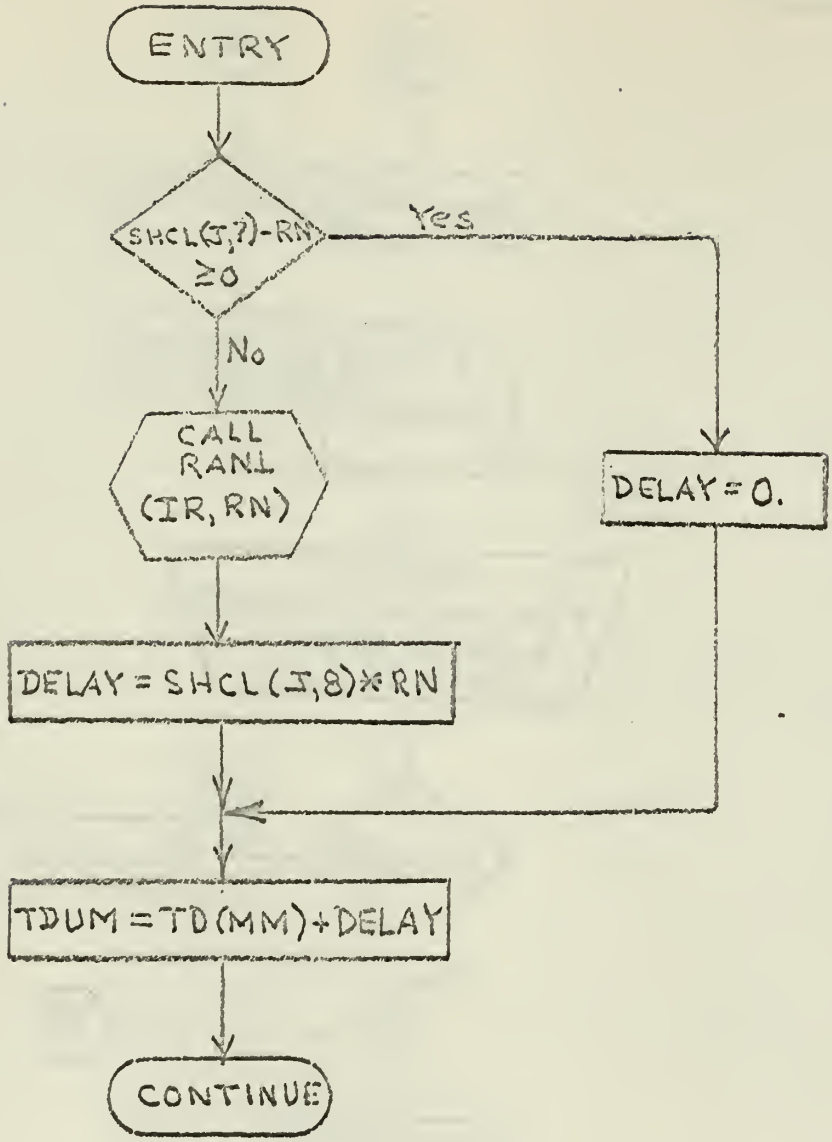


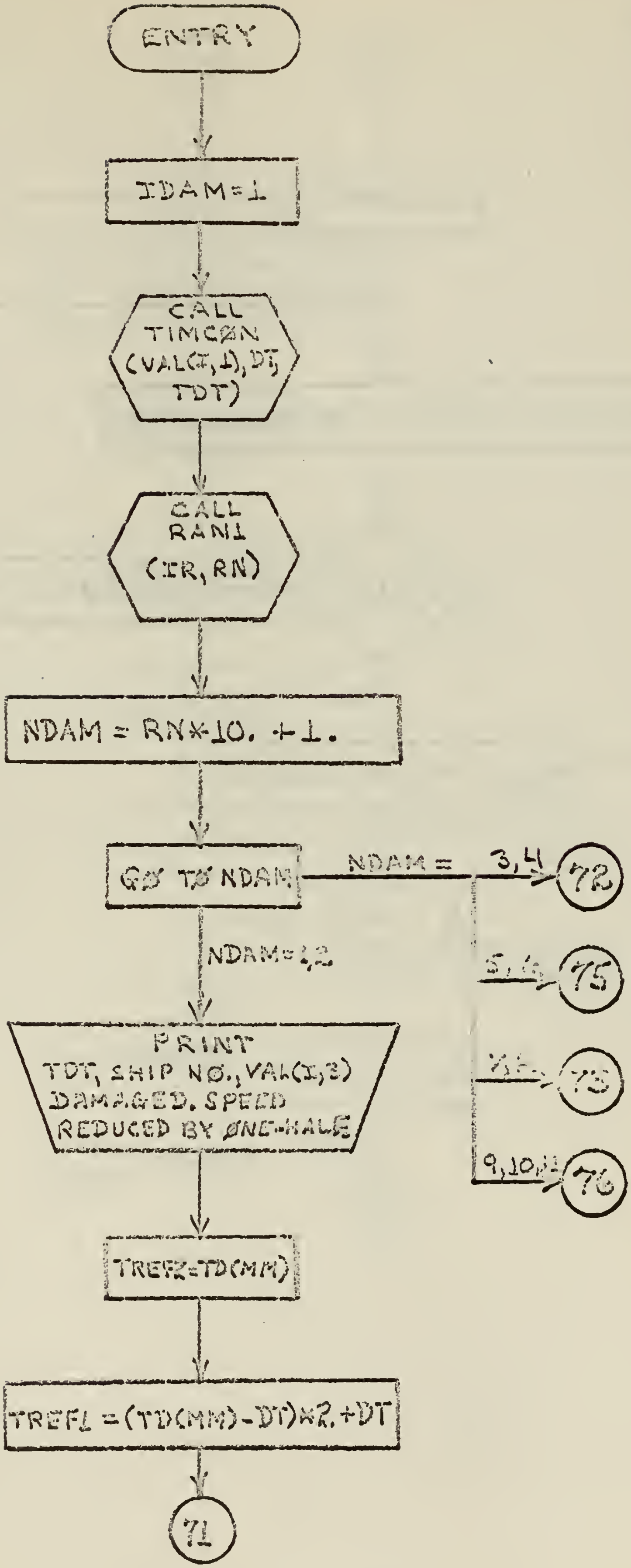
8. CONTD

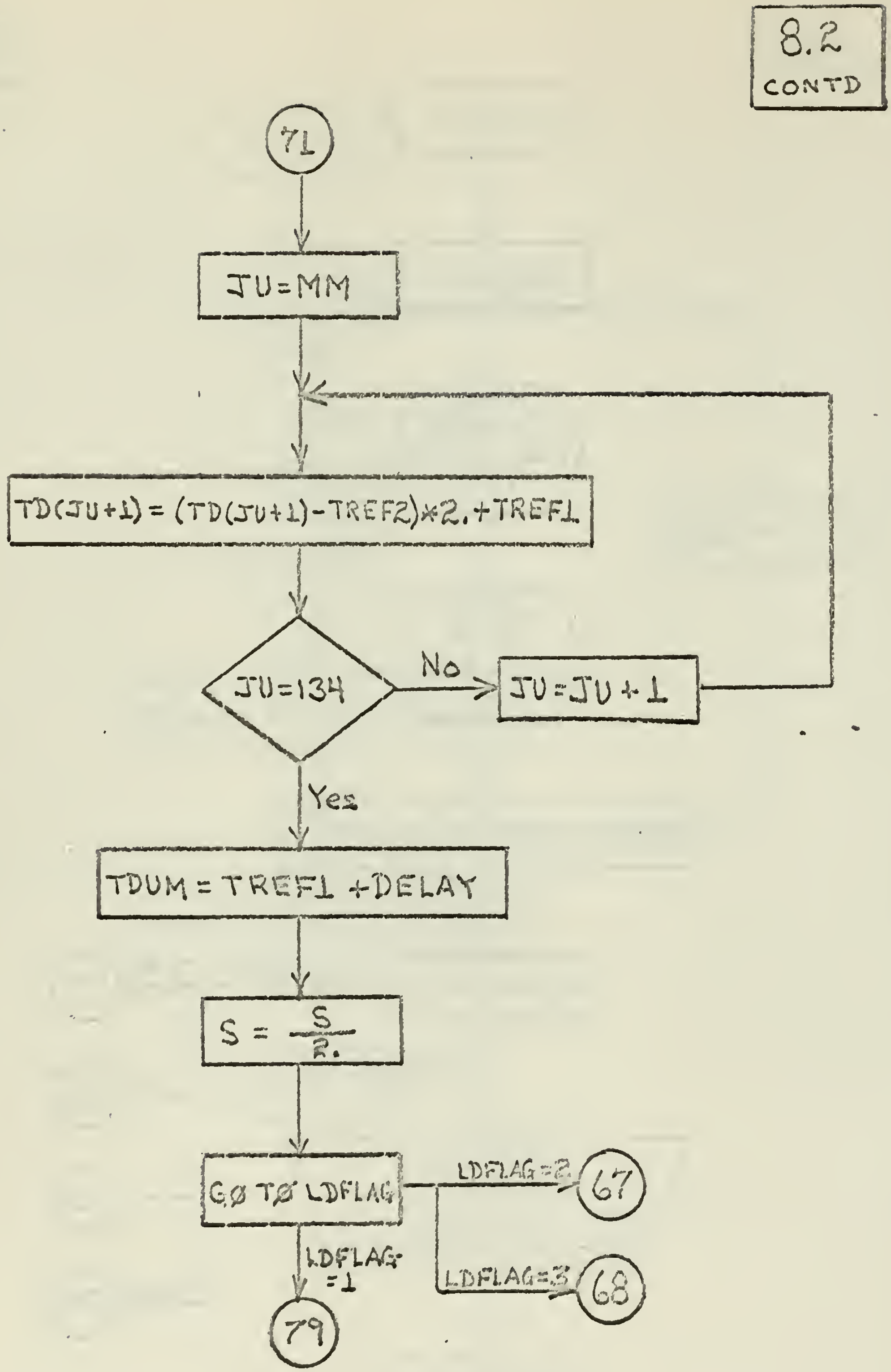


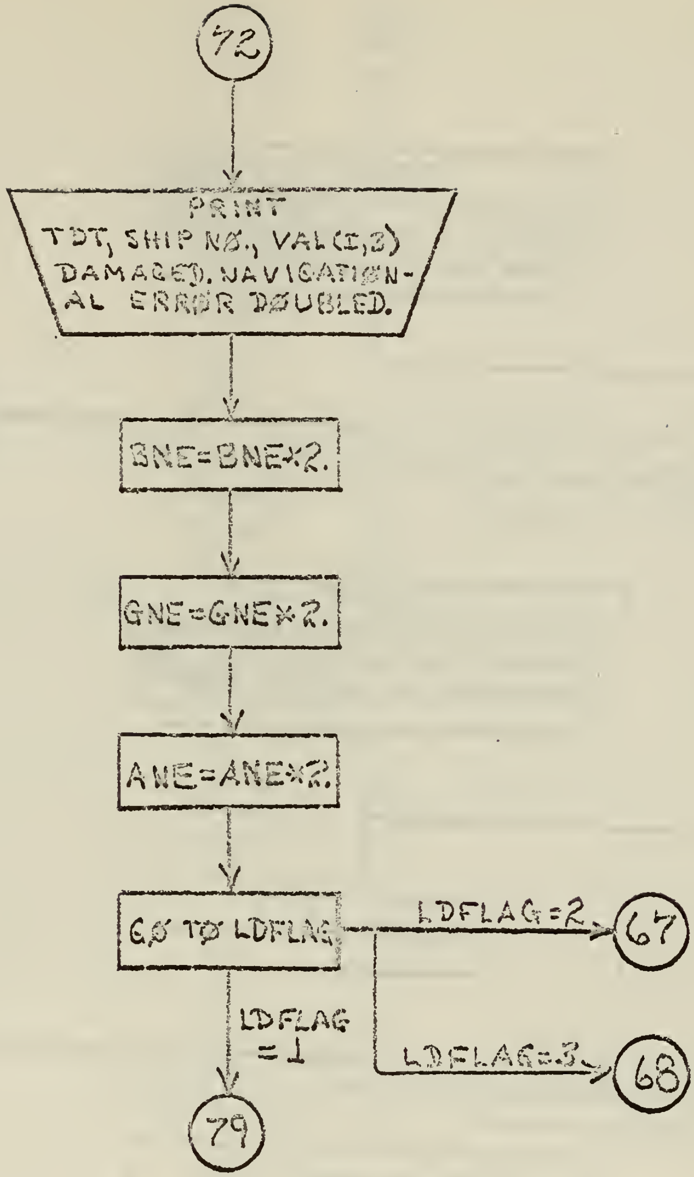
60
MM=MM+1.
CALL XTLEGN (XLCØD, L)
PRINT TIP SHIP NØ., VAL(I,3) ARRIVES AT IP FØR LEG NØ., L.
K=NTØTLG
No
K=K+1
64
Yes
70
CONTINUE

8.1

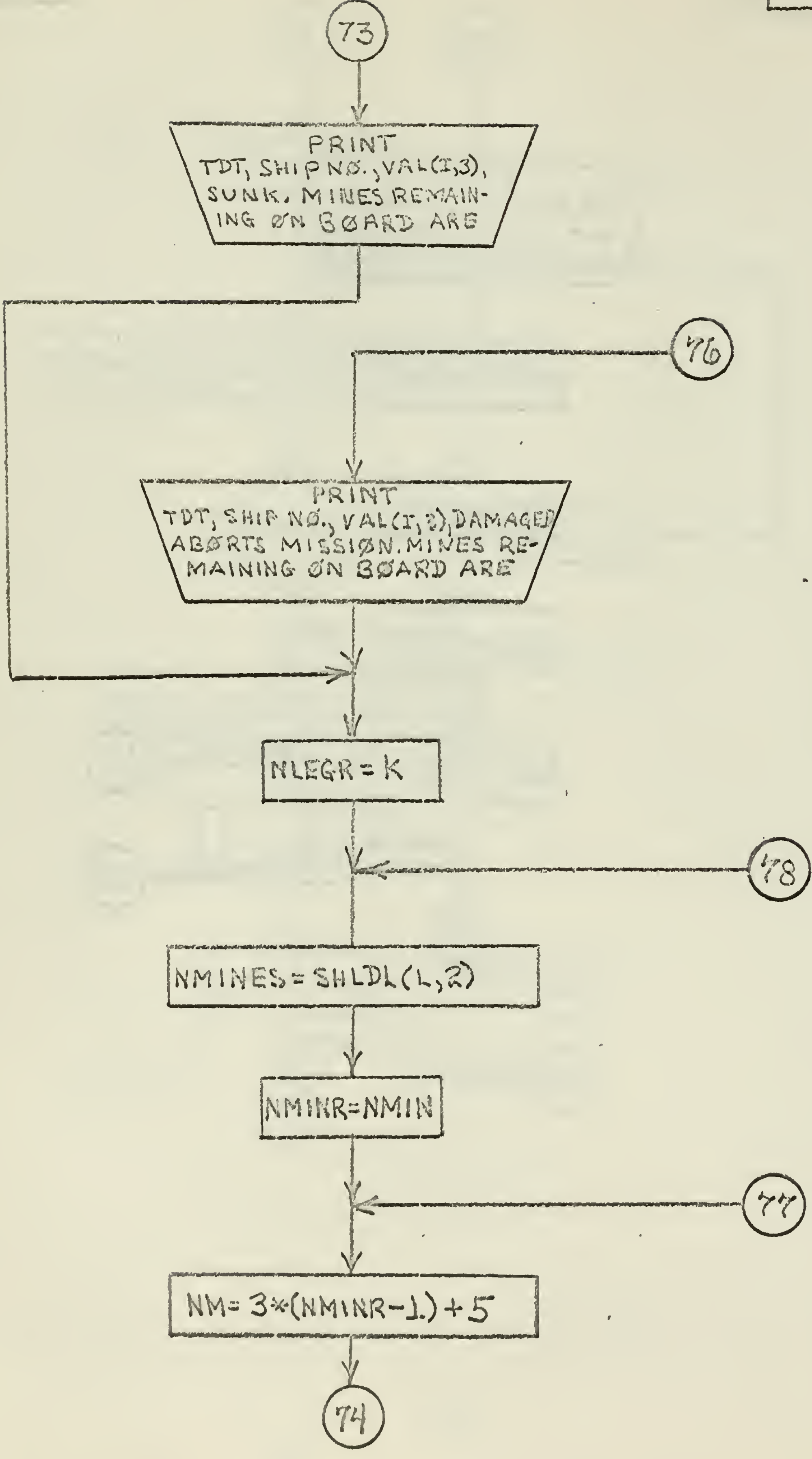

ENTRY
SHCL(J,7)-RN ≥0
Yes
No
CALL RAN1 (IR, RN)
DELAY = 0.
DELAY = SHCL(J,8)*RN
TDUM = TD(MM)+DELAY
CONTINUE


ENTRY
IDAM=1
CALL TIMCØN (VAL(I,1), DT, TDT)
CALL RAN1 (IR, RN)
NDAM = RN*10. +1.
GØ TØ NDAM
NDAM =
3,4
72
5,6
75
9,10
76
NDAM=1,2
PRINT TDT, SHIP NØ., VAL(I,2) DAMAGED. SPEED REDUCED BY ØNE-HALF
TREF2=TD(MM)
TREF1 =(TD(MM)-DT)*2.+DT
71

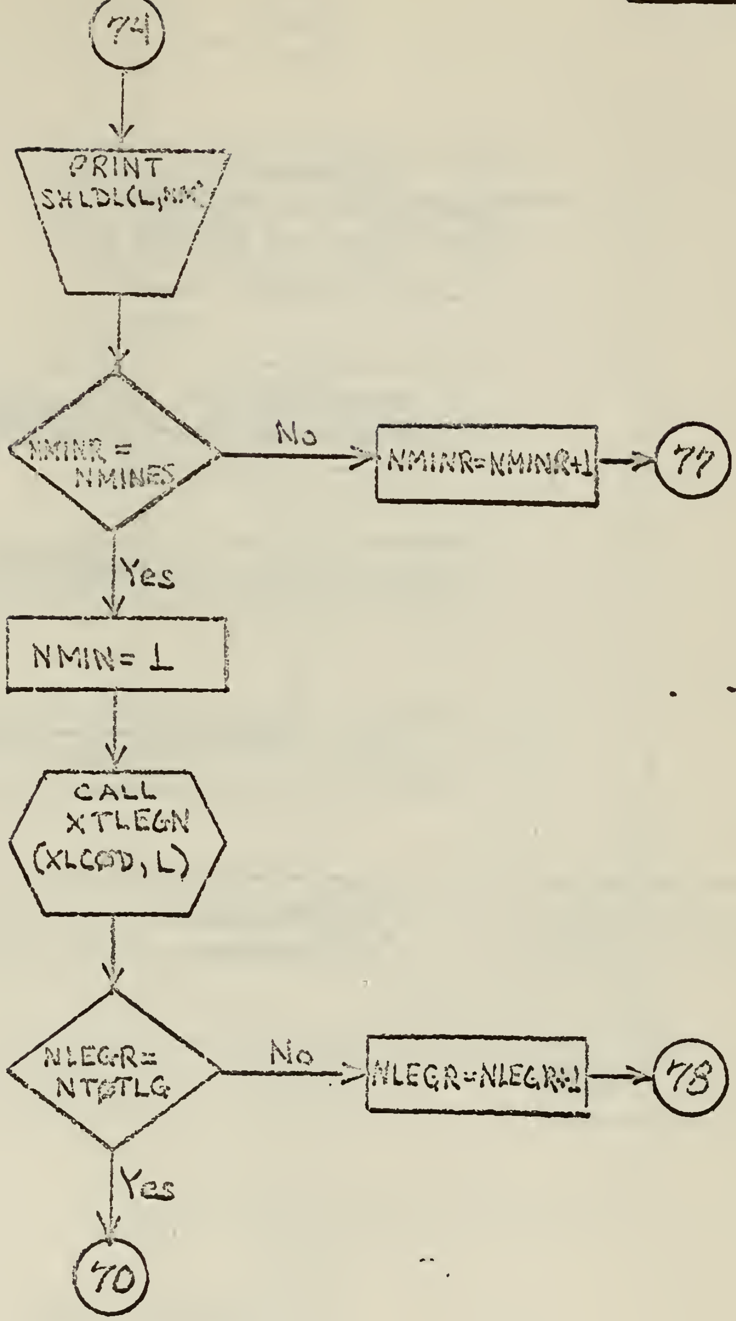

8.2
CONTD
71
JU=MM
TD(JU+1) = (TD(JU+1)-TREF2)*2.+TREF1
JU=134
No
JU=JU+1
Yes
TDUM = TREF1 +DELAY
S = S/2.
GØ TØ LDFLAG
LDFLAG=2
67
LDFLAG=3
68
LDFLAG =1
79


72
PRINT
TDT, SHIP NØ., VAL(I,3)
DAMAGED. NAVIGATIØN-
AL ERRØR DØUBLED.
BNE=BNE*2.
GNE=GNE*2.
ANE=ANE*2.
GØ TØ LDFLAG
LDFLAG=2
67
LDFLAG=3
68
LDFLAG
=1
79

8.2 CONT'D

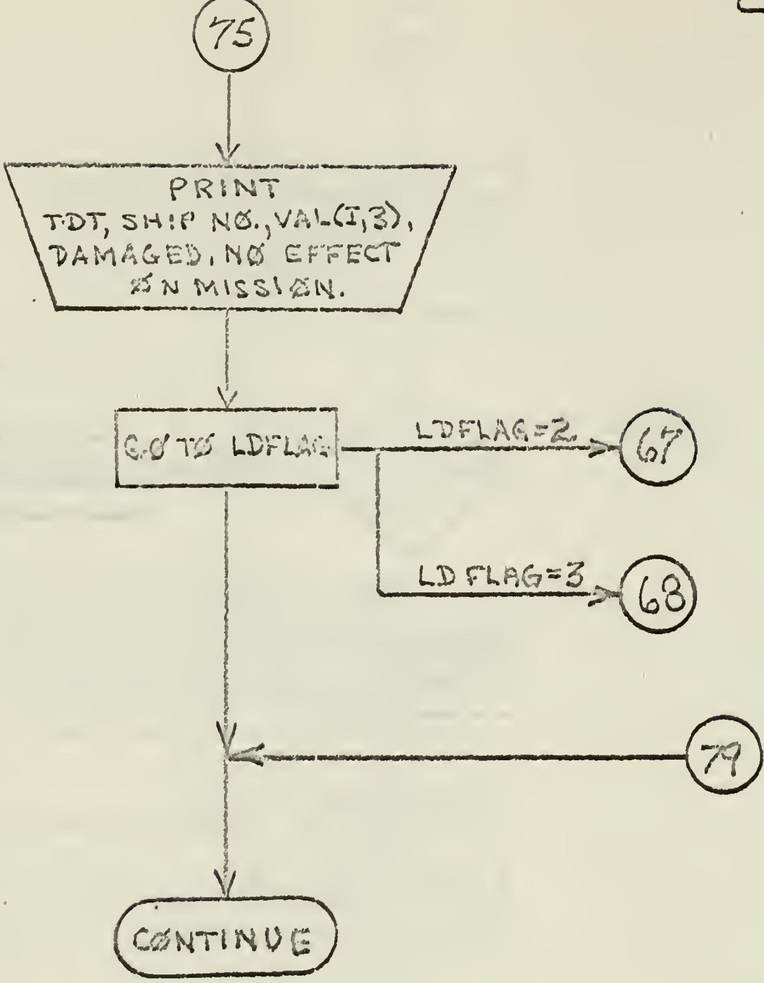

73
PRINT TDT, SHIP NØ., VAL(I,3), SUNK. MINES REMAINING ØN BØARD ARE
76
PRINT TDT, SHIP NØ., VAL(I,3), DAMAGED ABØRTS MISSIØN. MINES REMAINING ØN BØARD ARE
NLEGR = K
78
NMINES = SHLDL(L,2)
NMINR=NMIN
77
NM= 3*(NMINR-1.)+5
74

8.2 CONT'D

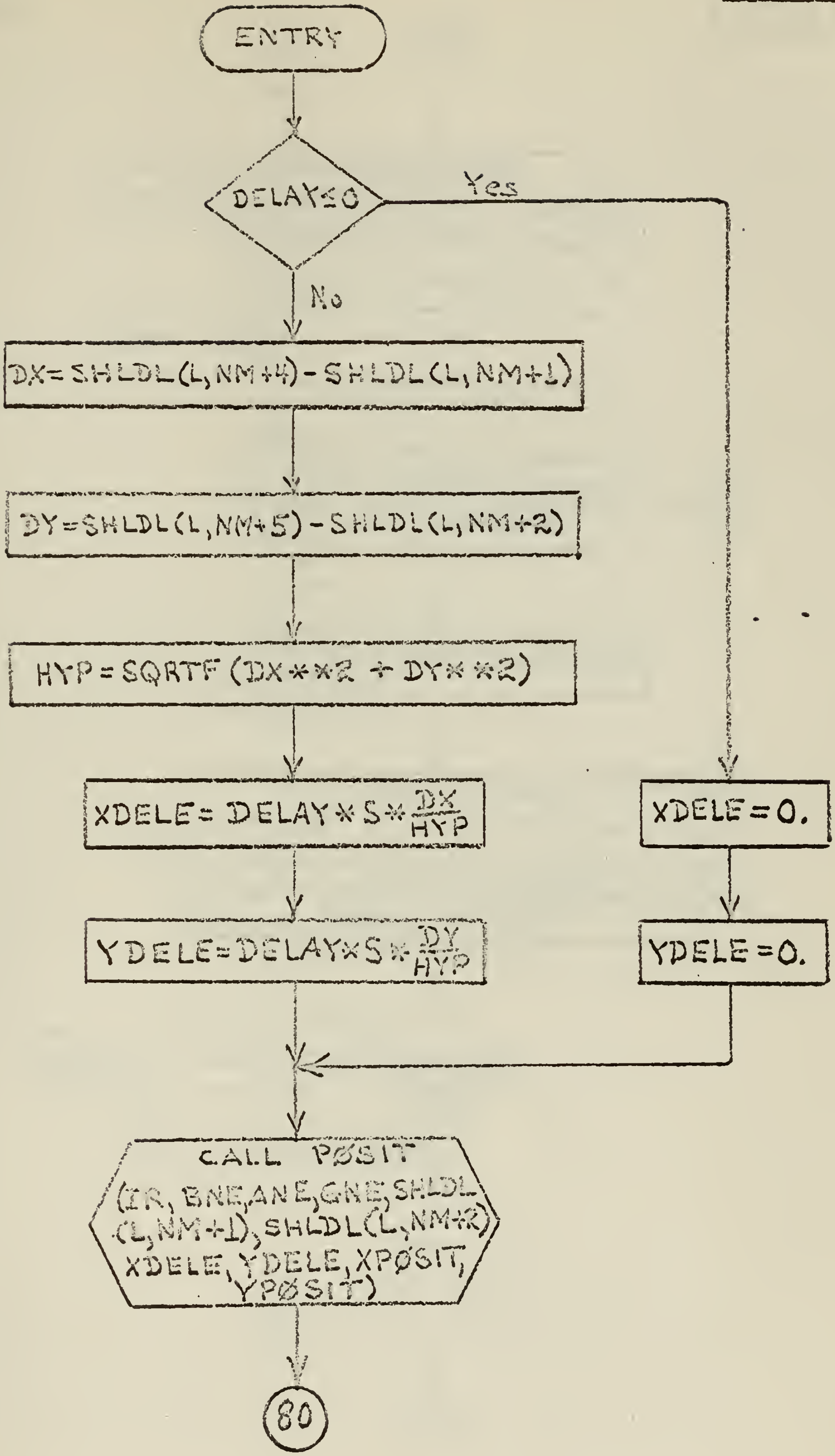


74
PRINT SHLDL(L,NM)
NMINR = NMINES
No
NMINR=NMINR+1
77
Yes
NMIN= 1
CALL XTLEGN (XLCØD, L)
NLEGR= NTØTLG
No
NLEGR=NLEGR+1
78
Yes
70

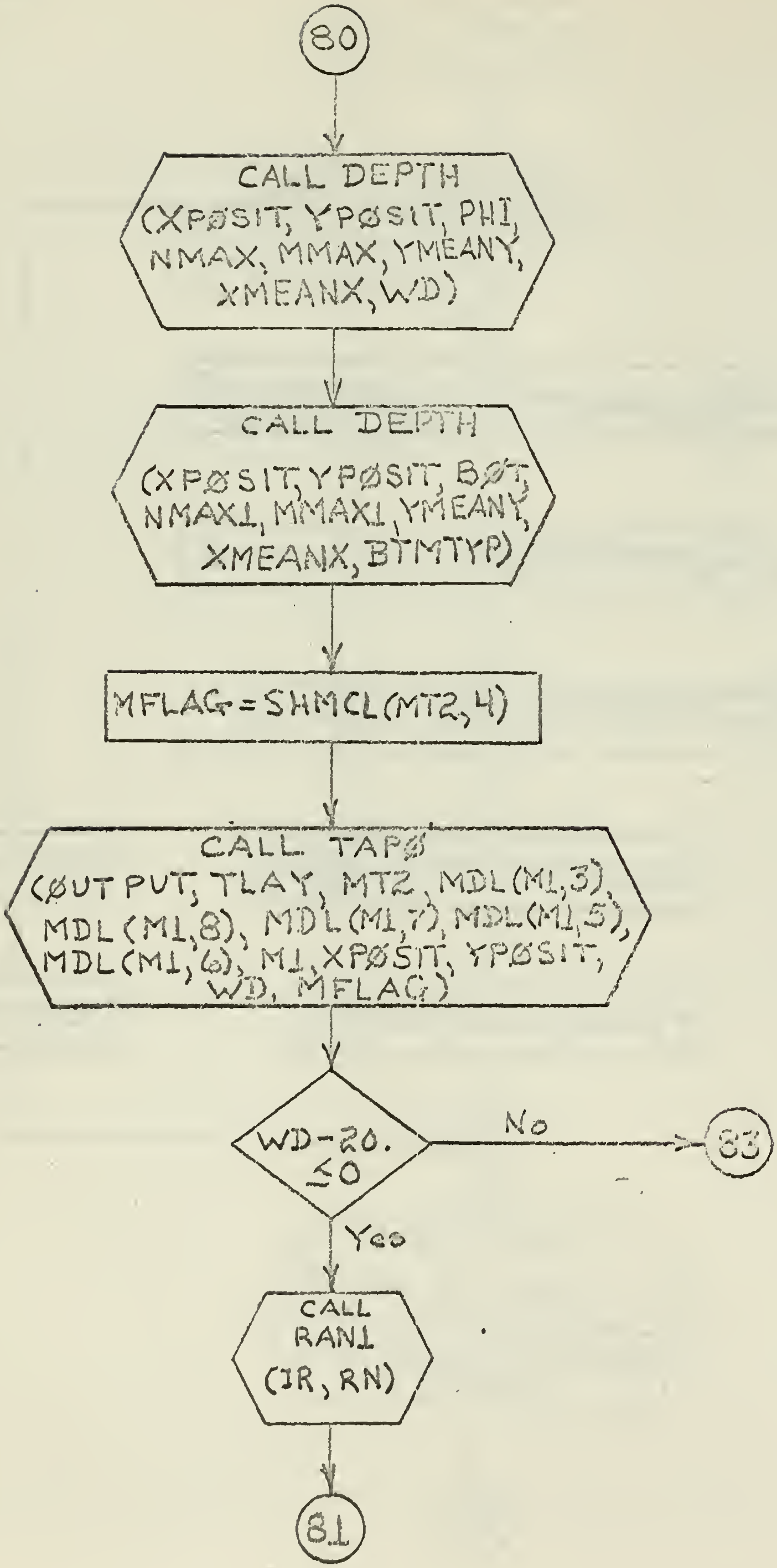
8.2 CONTD


75
PRINT
TDT, SHIP NØ., VAL(I,3), DAMAGED, NØ EFFECT ØN MISSIØN.
GØ TØ LDFLAG
LDFLAG=2
67
LDFLAG=3
68
79
CØNTINUE

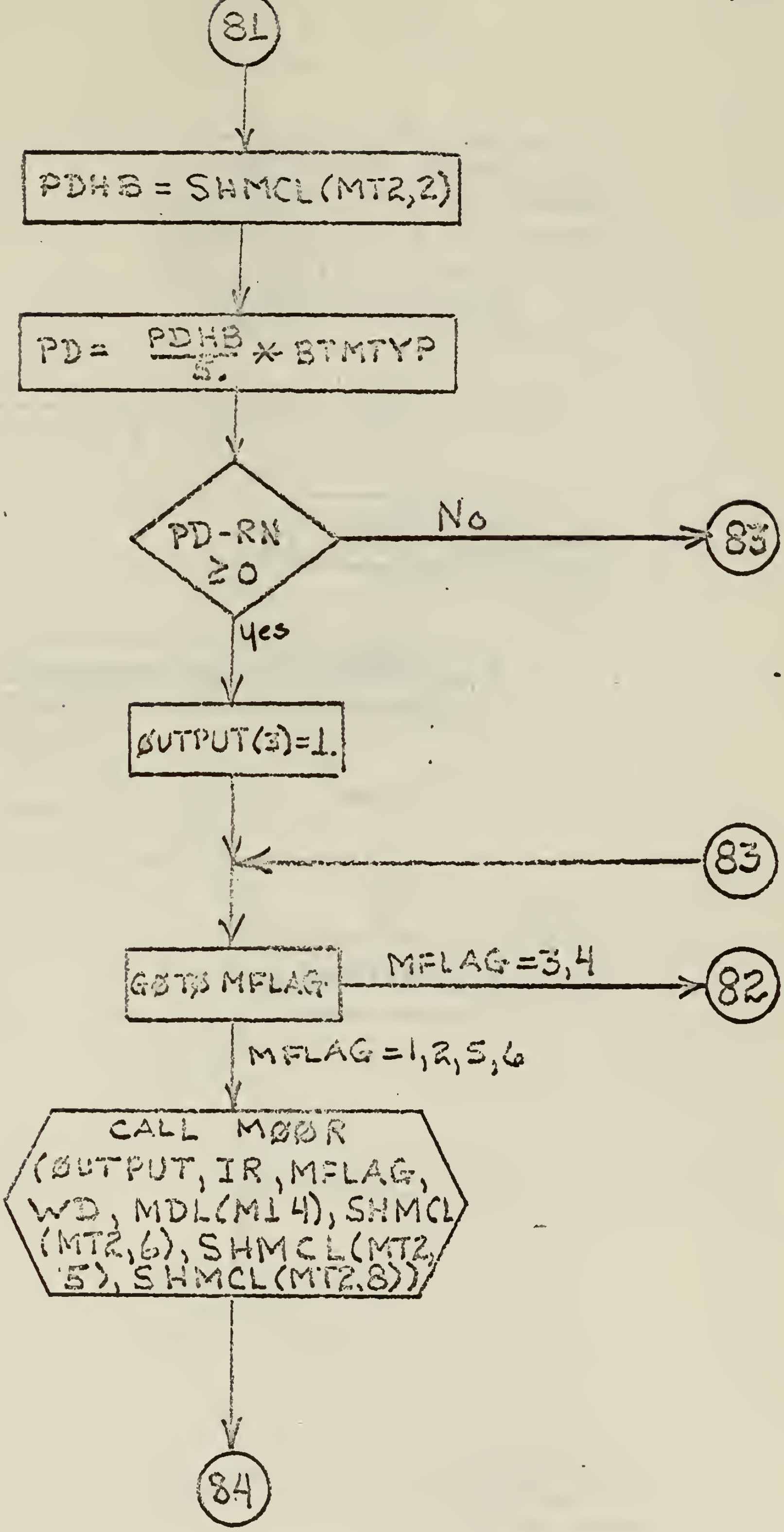
8.3


ENTRY
DELAY≤0
Yes
No
DX=SHLDL(L,NM+4)-SHLDL(L,NM+1)
DY=SHLDL(L,NM+5)-SHLDL(L,NM+2)
HYP=SQRTF(DX**2 + DY**2)
XDELE=DELAY*S*DX/HYP
YDELE=DELAY*S*DY/HYP
XDELE=0.
YDELE=0.
CALL PØSIT (IR, BNE, ANE, GNE, SHLDL(L,NM+1), SHLDL(L,NM+2) XDELE, YDELE, XPØSIT, YPØSIT)
80

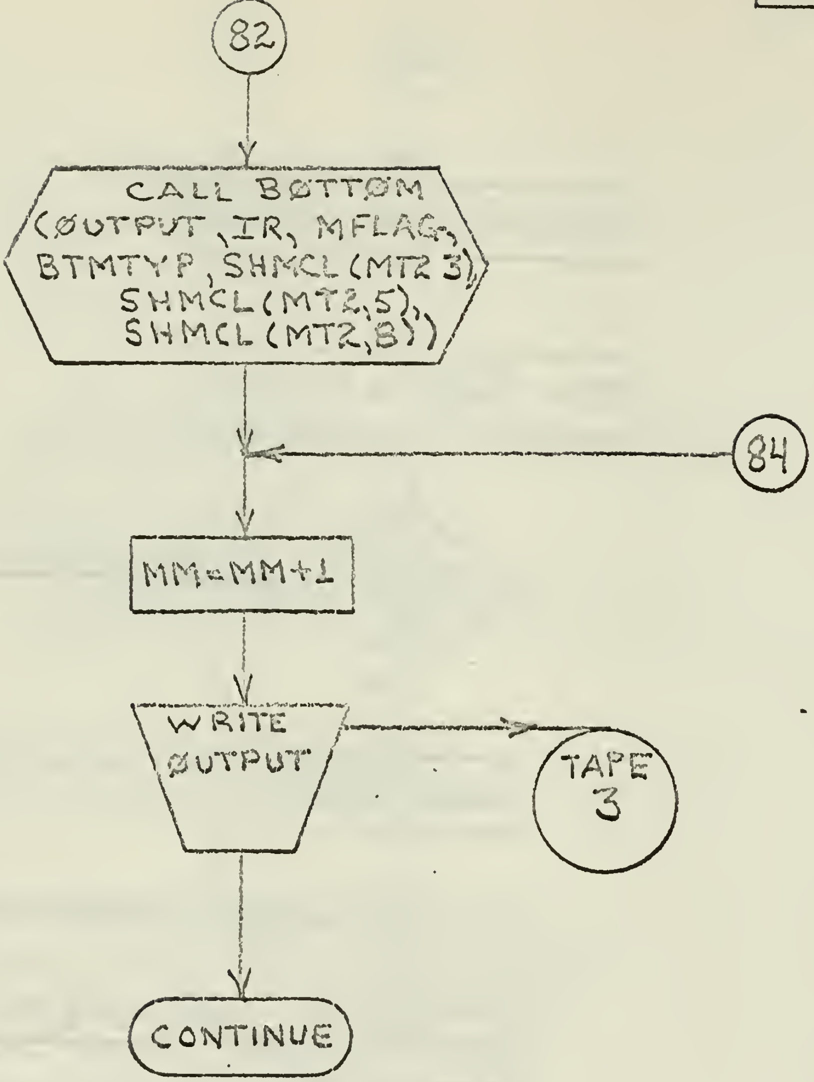
8.3
CONTD


80
CALL DEPTH
(XPØSIT, YPØSIT, PHI, NMAX, MMAX, YMEANY, XMEANX, WD)
CALL DEPTH
(XPØSIT, YPØSIT, BØT, NMAX1, MMAX1, YMEANY, XMEANX, BTMTYP)
MFLAG=SHMCL(MT2,4)
CALL TAPØ
(ØUTPUT, TLAY, MT2, MDL(M1,3), MDL(M1,8), MDL(M1,7), MDL(M1,5), MDL(M1,6), M1, XPØSIT, YPØSIT, WD, MFLAG)
WD-20.
≤0
No
83
Yes
CALL
RAN1
(IR, RN)
81

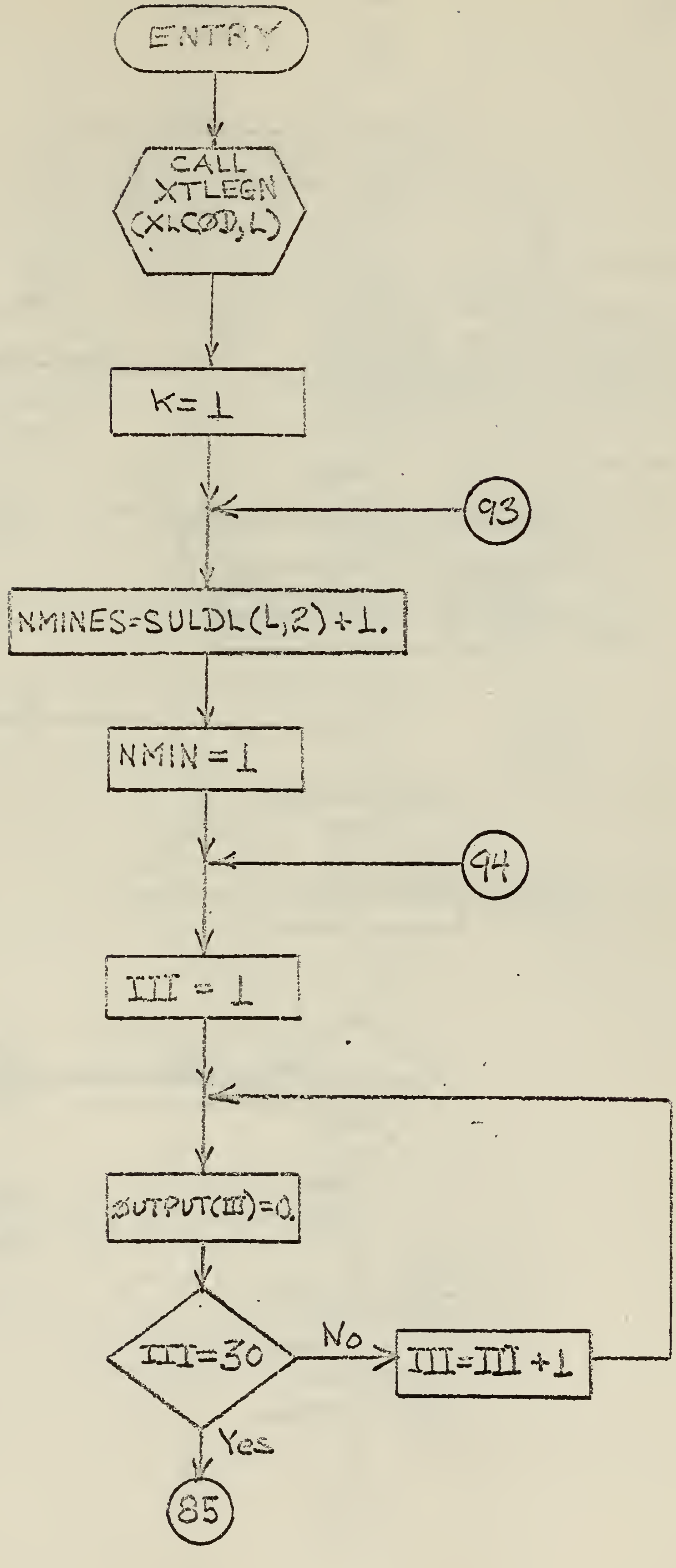
8.3 CONTD

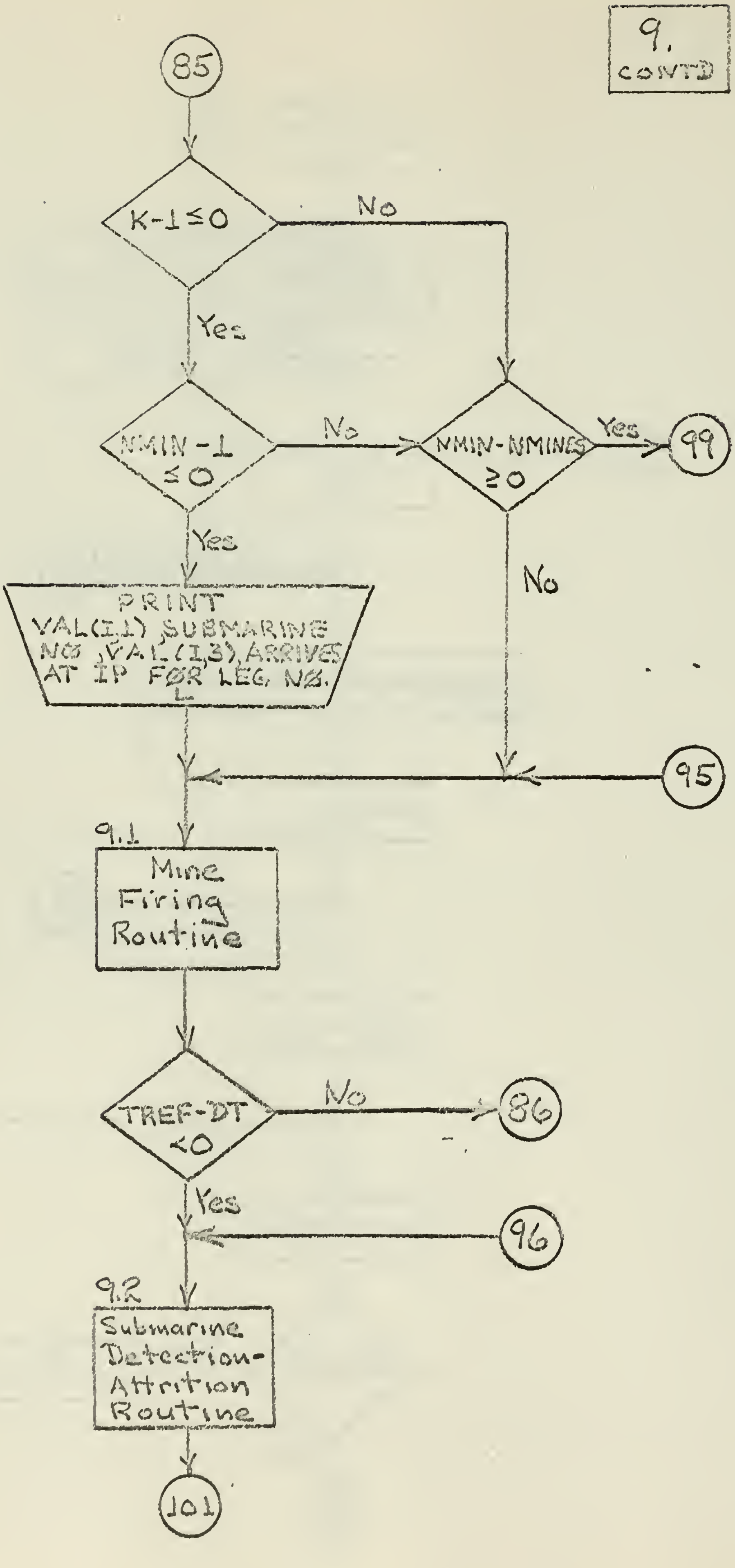

81
PDHB = SHMCL(MT2,2)
PD = PDHB / 5. * BTMTYP
PD-RN ≥ 0
No
83
yes
ØUTPUT(3)=1.
83
GØTØ MFLAG
MFLAG=3,4
82
MFLAG=1,2,5,6
CALL MØØR (ØUTPUT, IR, MFLAG, WD, MDL(M14), SHMCL (MT2,6), SHMCL(MT2, 5), SHMCL(MT2,8))
84

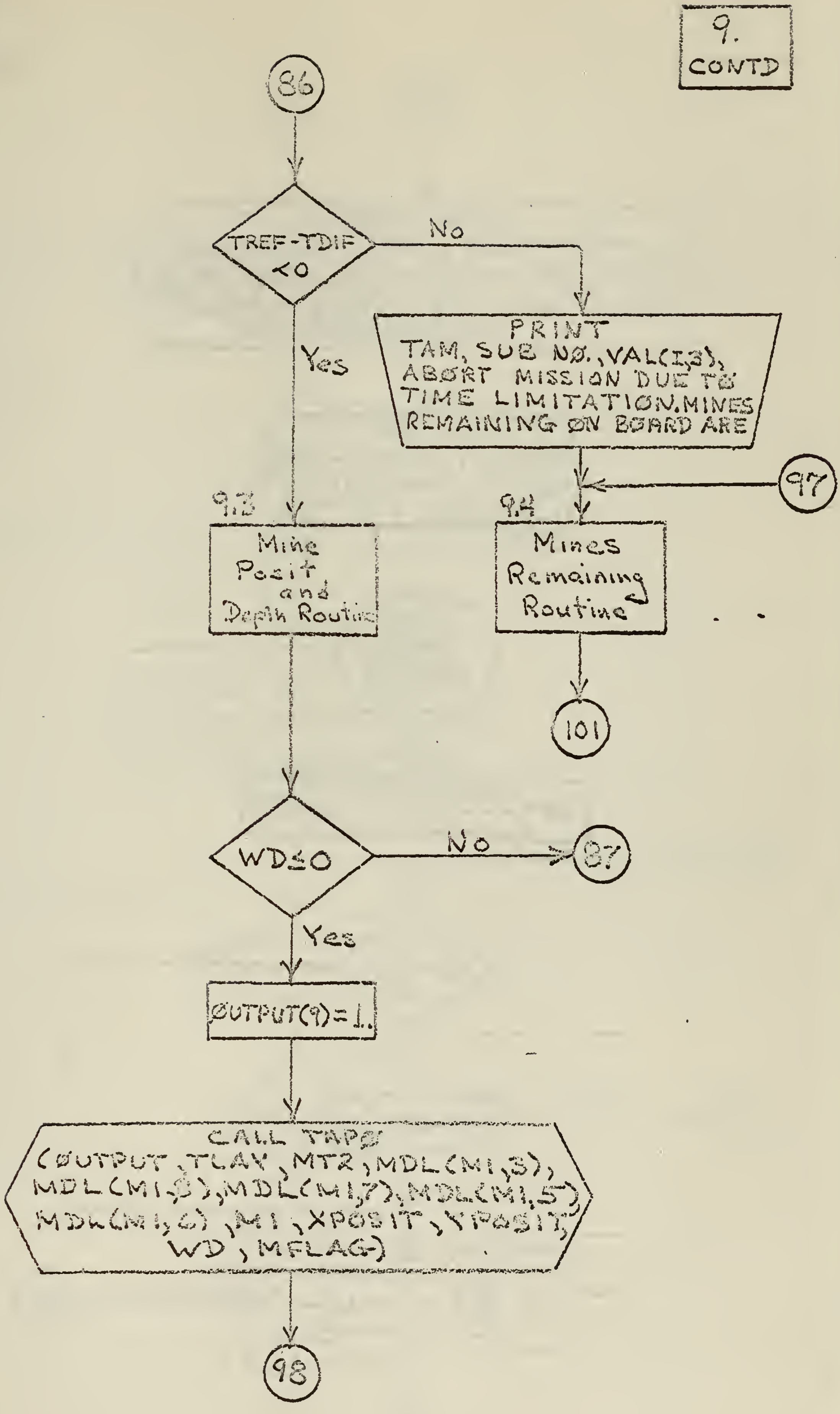
8.3 CONTD


82
CALL BØTTØM
(ØUTPUT, IR, MFLAG,
BTMTYP, SHMCL(MT2,3),
SHMCL(MT2,5),
SHMCL(MT2,8))
84
MM=MM+1
WRITE
ØUTPUT
TAPE
3
CONTINUE

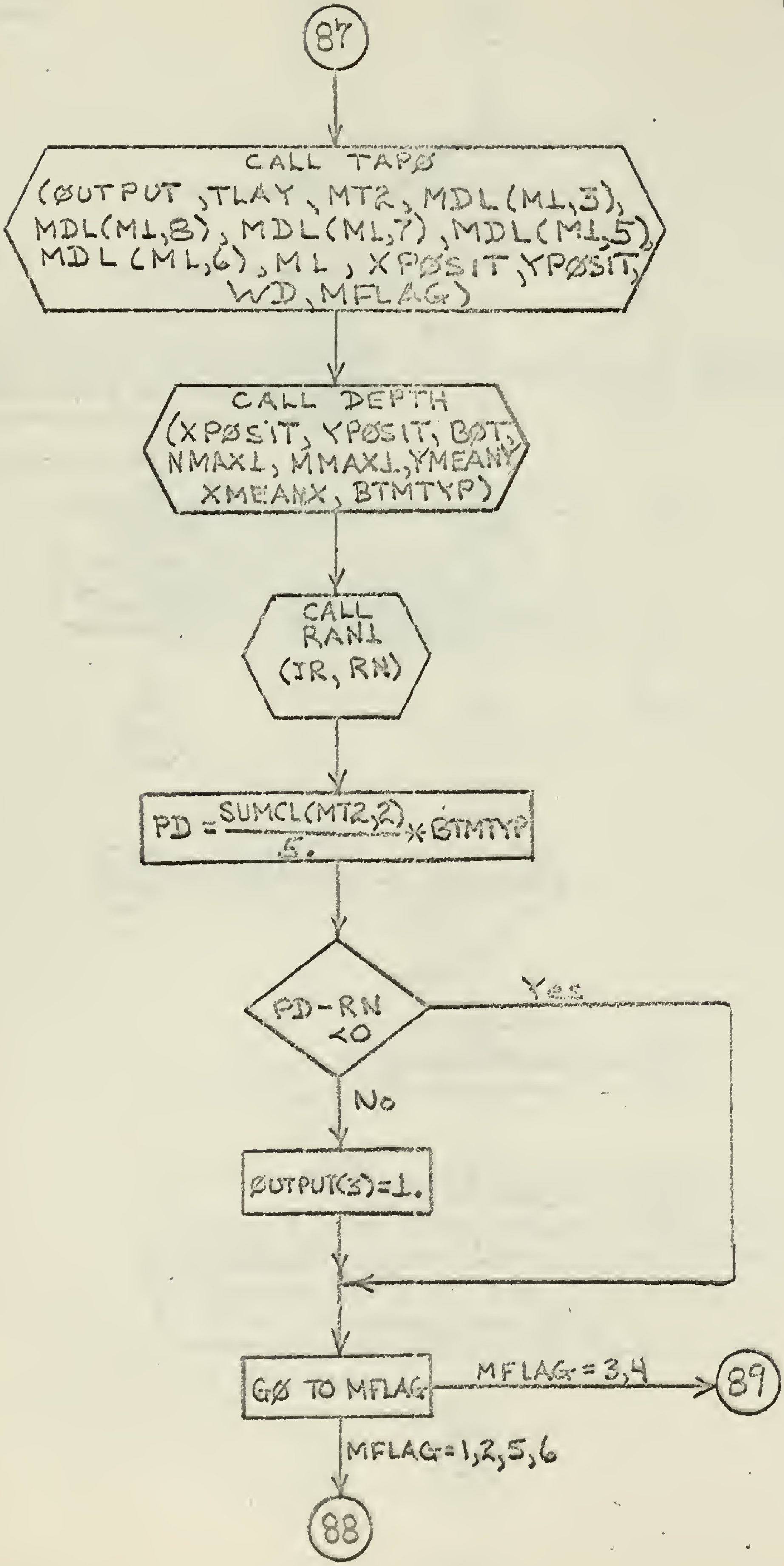
9.


ENTRY
CALL XTLEGN (XLCØD, L)
K = 1
93
NMINES = SULDL(L,2) + 1.
NMIN = 1
94
III = 1
ØUTPUT(III) = 0.
III = 30
No
III = III + 1
Yes
85

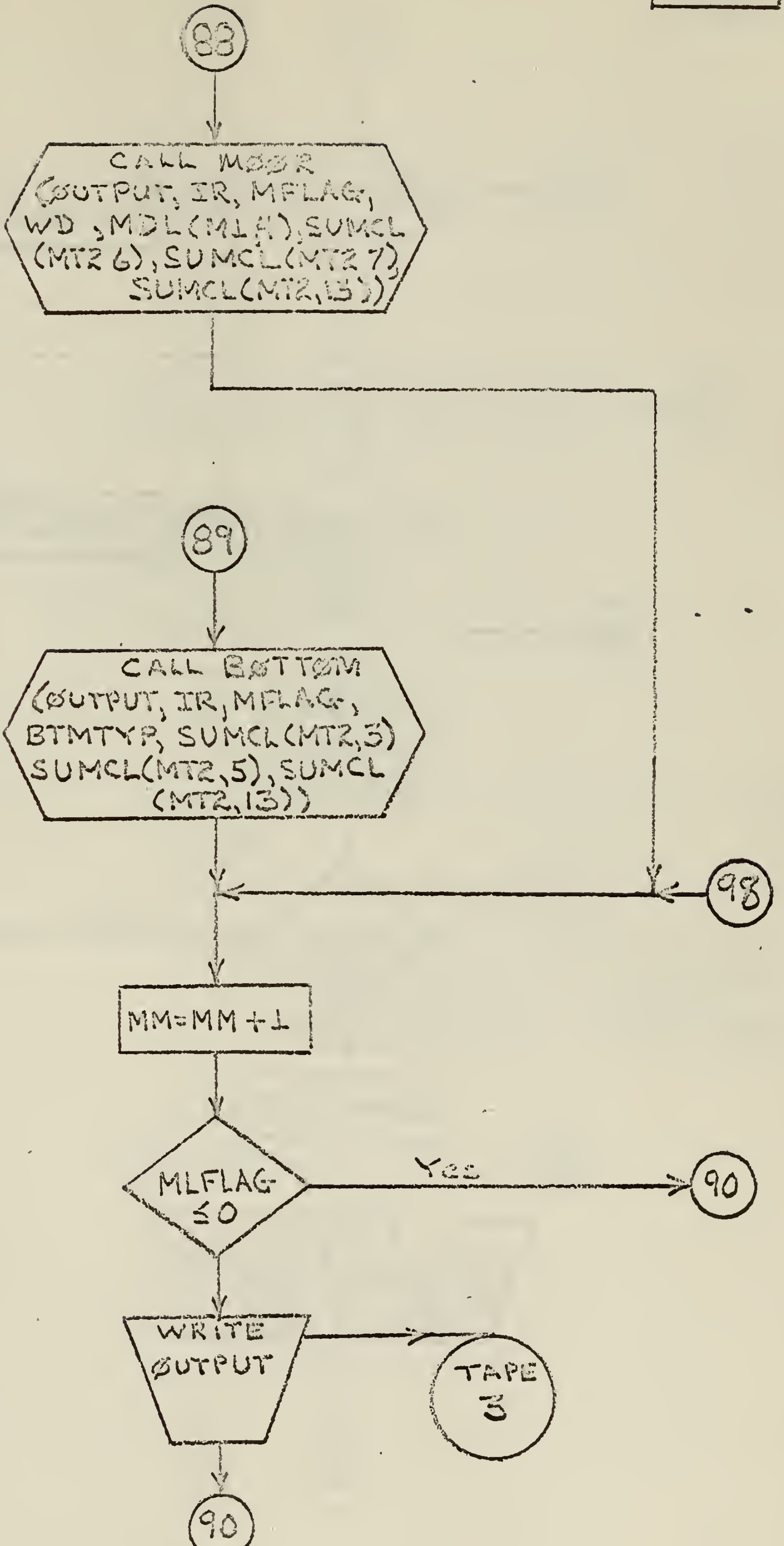

9. CONT'D
85
K-1≤0
No
Yes
NMIN-1 ≤0
No
NMIN-NMINES ≥0
Yes
99
Yes
No
PRINT VAL(I,1), SUBMARINE NØ, VAL(I,3), ARRIVES AT IP FØR LEG NØ. L
95
9.1
Mine Firing Routine
TREF-DT <0
No
86
Yes
96
9.2
Submarine Detection-Attrition Routine
101

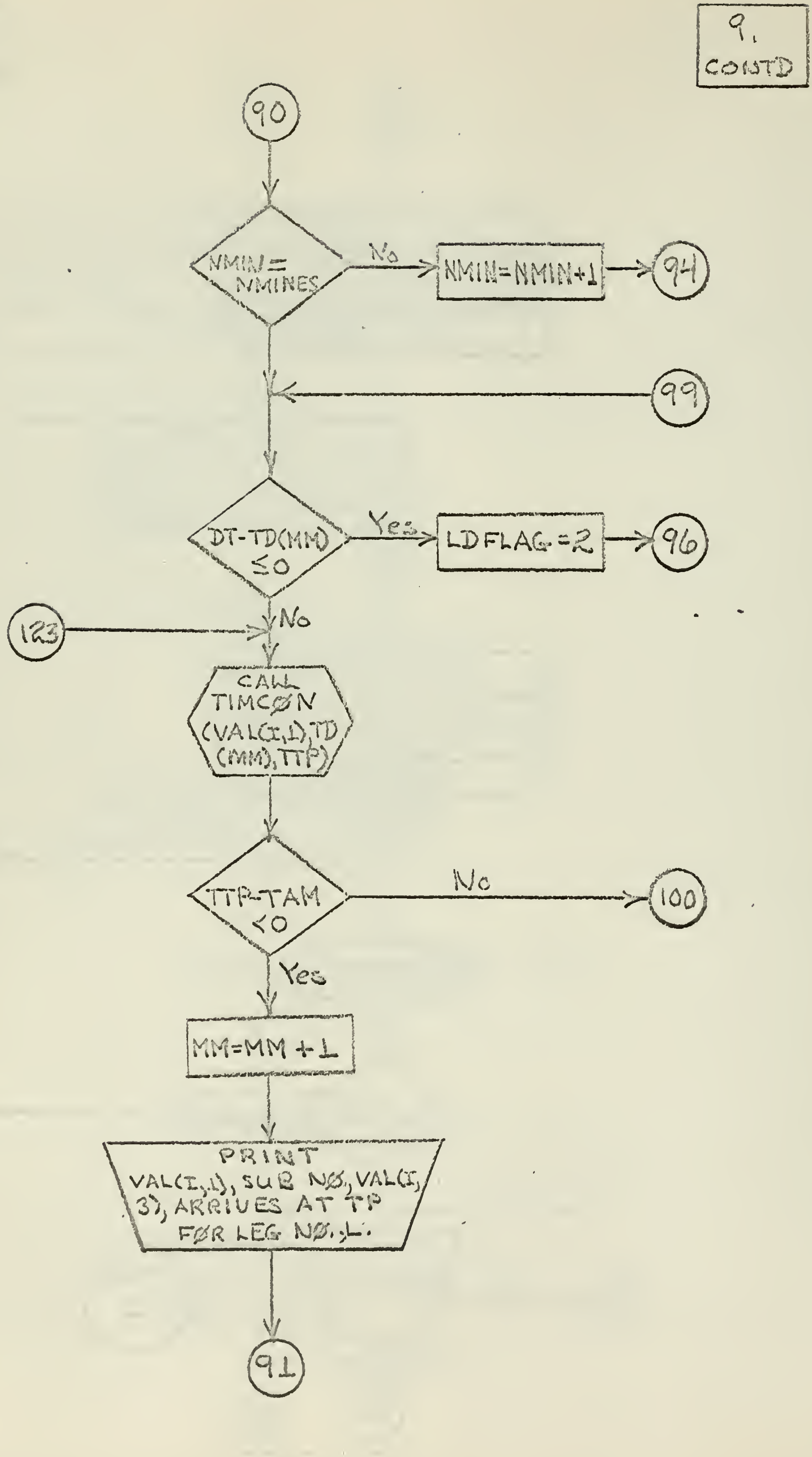

9. CONTD
86
TREF-TDIF <0
No
Yes
PRINT TAM, SUB NØ., VAL(I,3), ABØRT MISSION DUE TØ TIME LIMITATIØN. MINES REMAINING ØN BØARD ARE
97
9.3
Mine Posit and Depth Routine
9.4
Mines Remaining Routine
101
WD≤0
No
87
Yes
ØUTPUT(9)=1.
CALL TAPØ (ØUTPUT, TLAY, MTR, MDL(MI,3), MDL(MI,8), MDL(MI,7), MDL(MI,5) MDL(MI,6), MI, XPOSIT, YPOSIT, WD, MFLAG)
98

9.
CONTD

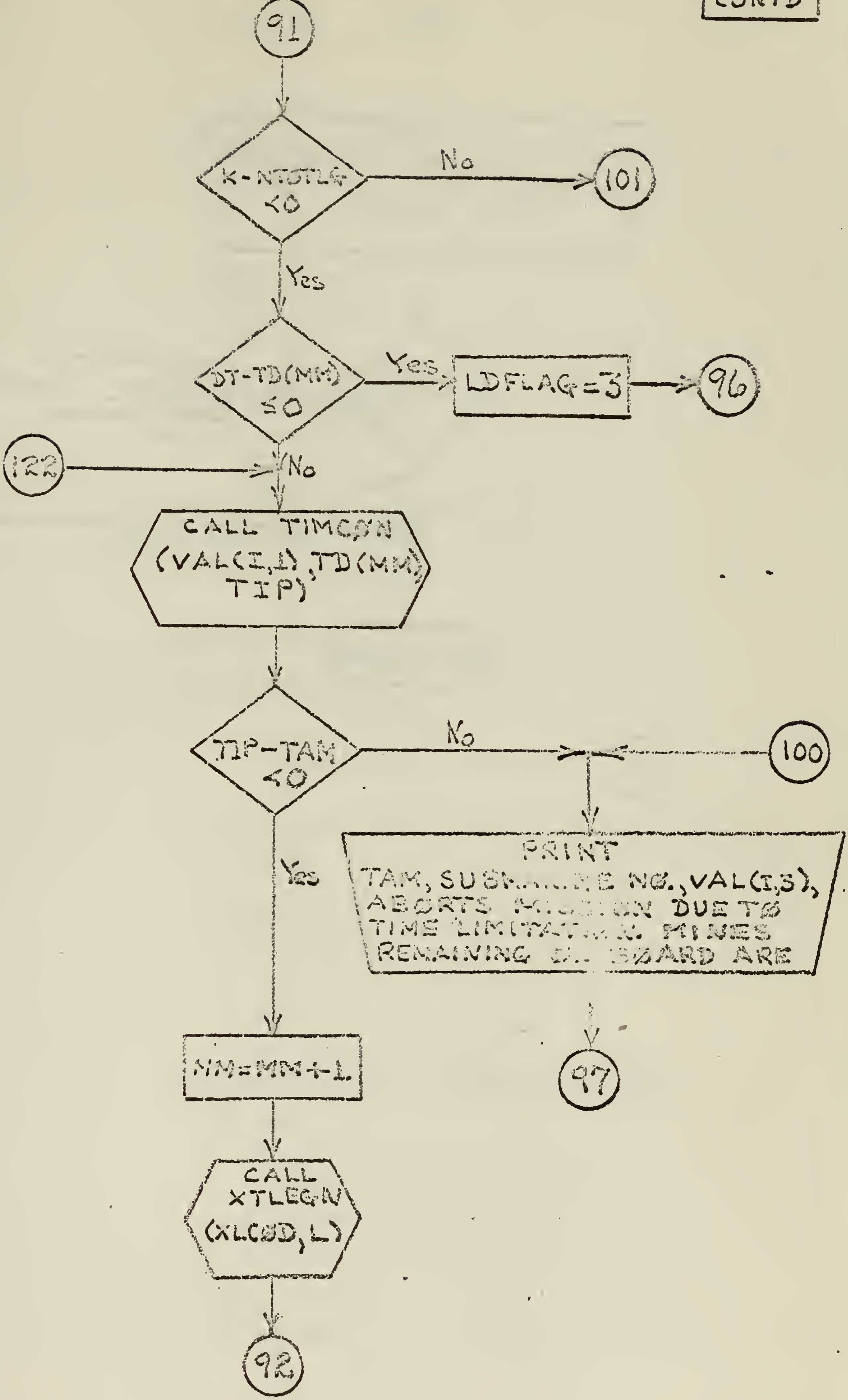

87
CALL TAPØ
(ØUTPUT, TLAY, MT2, MDL(M1,3),
MDL(M1,8), MDL(M1,7), MDL(M1,5),
MDL(M1,6), M1, XPØSIT, YPØSIT,
WD, MFLAG)
CALL DEPTH
(XPØSIT, YPØSIT, BØT,
NMAX1, MMAX1, YMEANY,
XMEANX, BTMTYP)
CALL
RAN1
(IR, RN)
PD = SUMCL(MT2,2) / .5 * BTMTYP
PD-RN
<0
Yes
No
ØUTPUT(3)=1.
GØ TO MFLAG
MFLAG=3,4
89
MFLAG=1,2,5,6
88

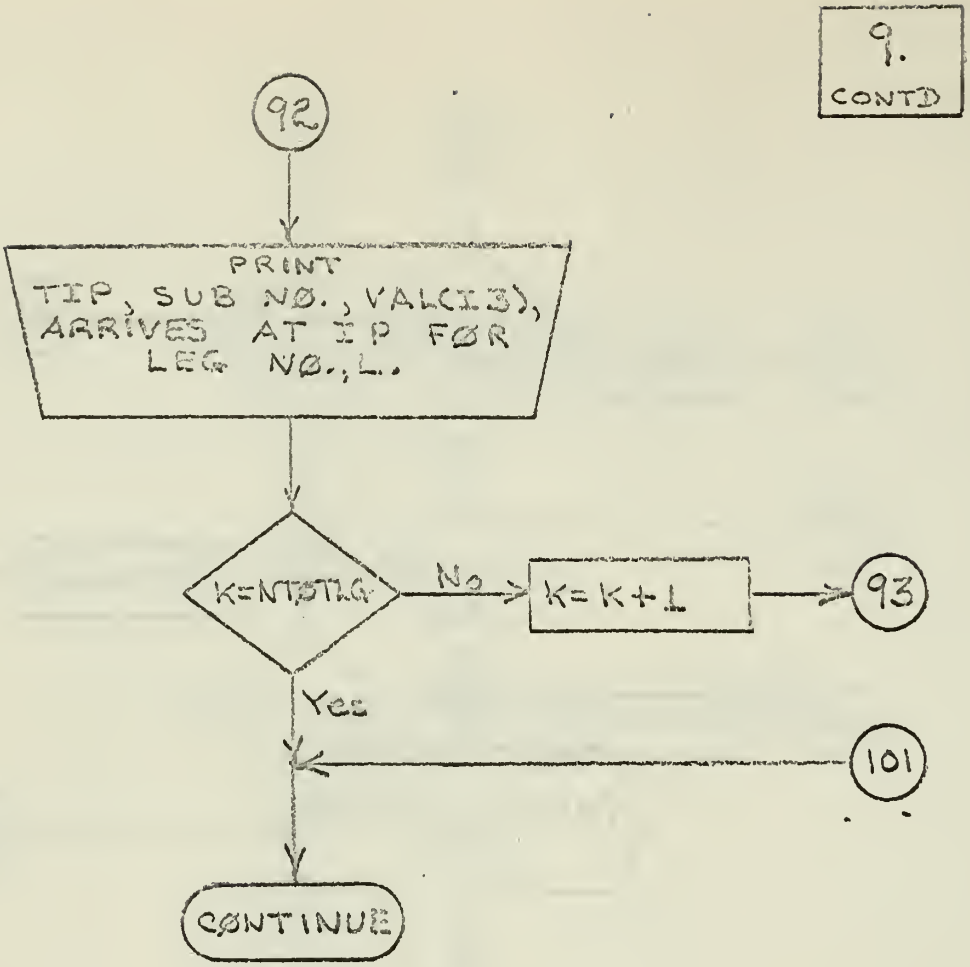
9.
CONTD


88
CALL MØØR (ØUTPUT, IR, MFLAG, WD ,MDL(M1H),SUMCL (MTZ 6),SUMCL(MTZ 7), SUMCL(MTZ,13))
89
CALL BØTTØM (ØUTPUT, IR, MFLAG, BTMTYP, SUMCL(MTZ,3) SUMCL(MTZ,5), SUMCL (MTZ,13))
98
MM=MM+1
MLFLAG ≤0
Yes
90
WRITE ØUTPUT
TAPE 3
90

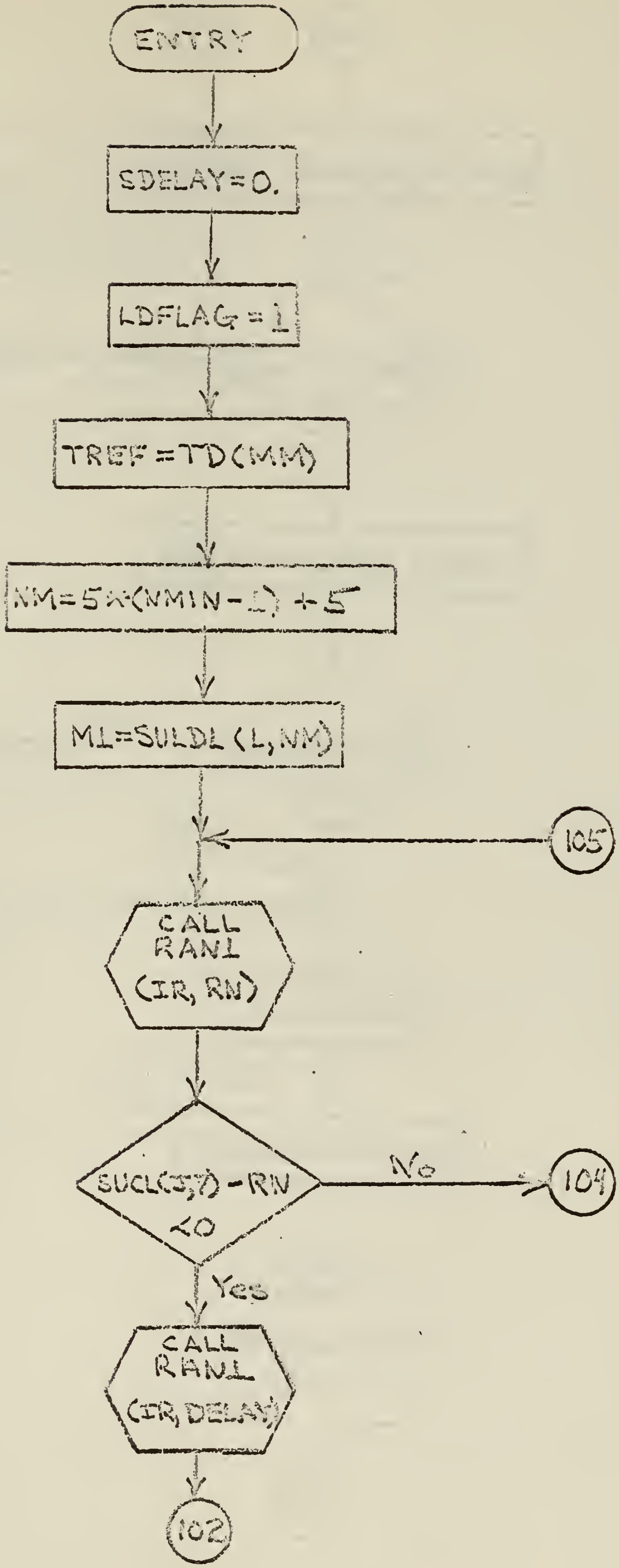

9.
CONTD
90
NMIN = NMINES
No
NMIN=NMIN+1
94
99
DT-TD(MM) ≤0
Yes
LDFLAG=2
96
No
123
CALL TIMCØN (VAL(I,1),TD(MM),TTP)
TTP-TAM <0
No
100
Yes
MM=MM + 1
PRINT VAL(I,1), SUB NØ., VAL(I,3), ARRIVES AT TP FØR LEG NØ.,L.
91

9. CONTD

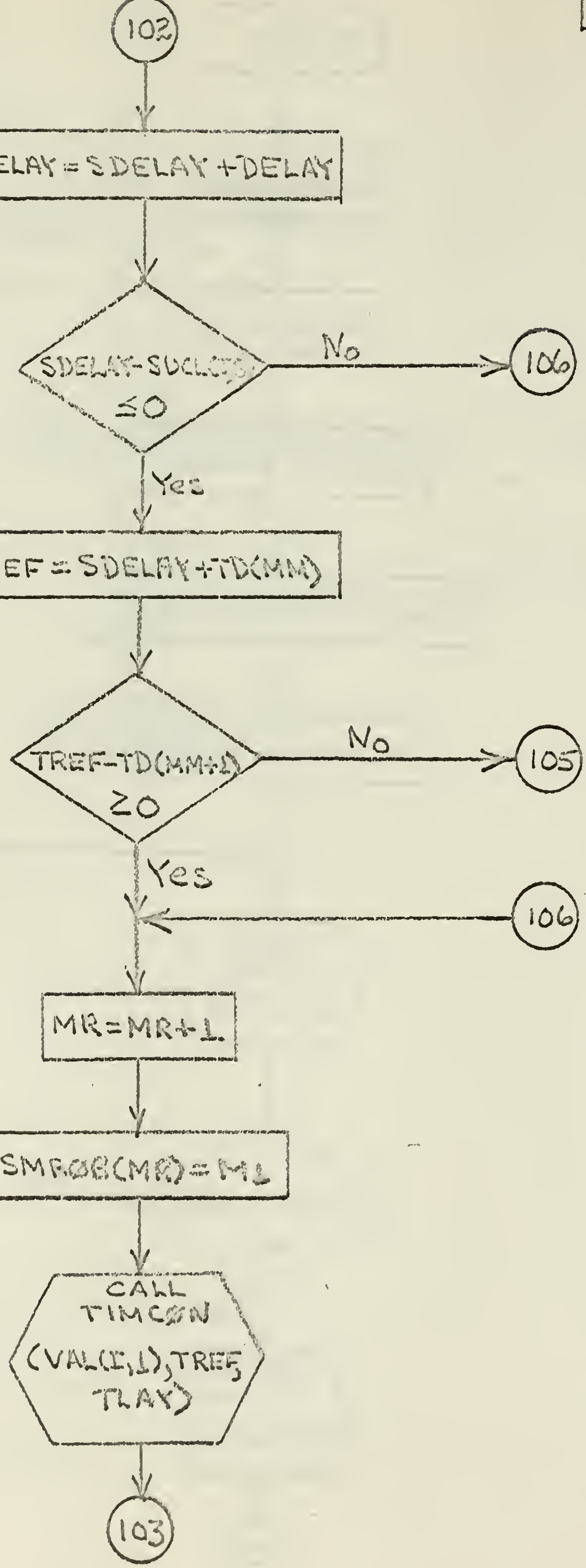

91
K-NTOTLG <0
No
101
Yes
DT-TD(MM) ≤0
Yes
LDFLAG=3
96
122
No
CALL TIMCØN (VAL(I,1),TD(MM), TIP)
TIP-TAM <0
No
100
Yes
PRINT
VAL(I,3),
DUE TØ
MINES
REMAINING
ARE
97
MM=MM+1
CALL XTLEGN (XLCØD,L)
92

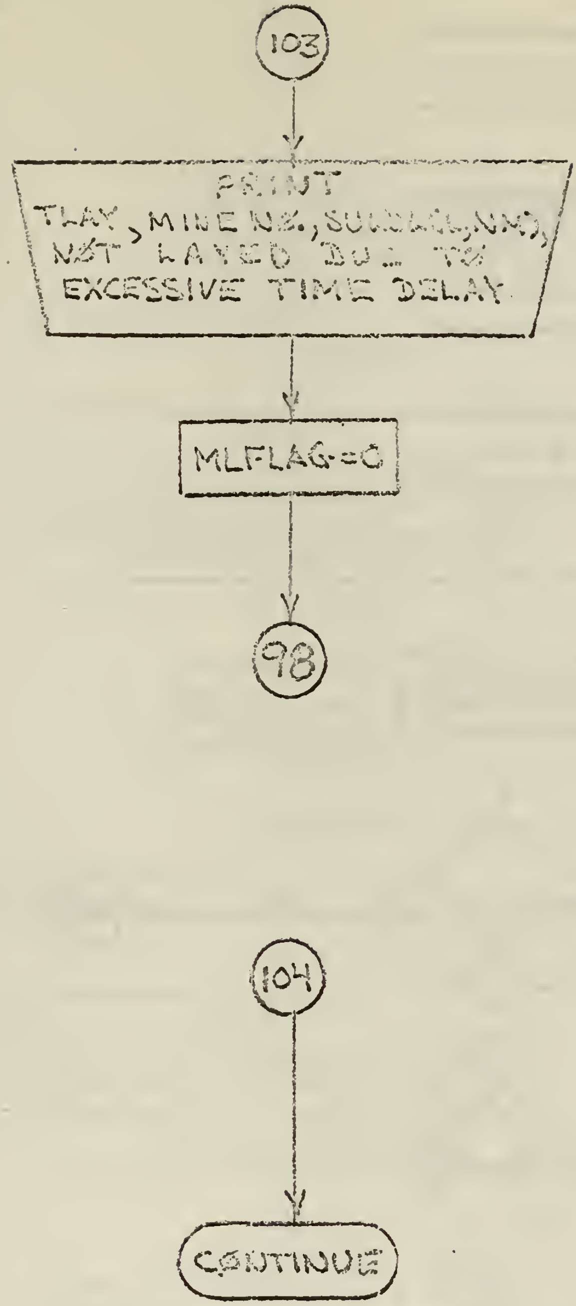

9. CONTD
92
PRINT TIP, SUB NØ., VAL(I3), ARRIVES AT IP FØR LEG NØ., L.
K=NTØTLG
No
K=K+1
93
Yes
101
CØNTINUE

9.1

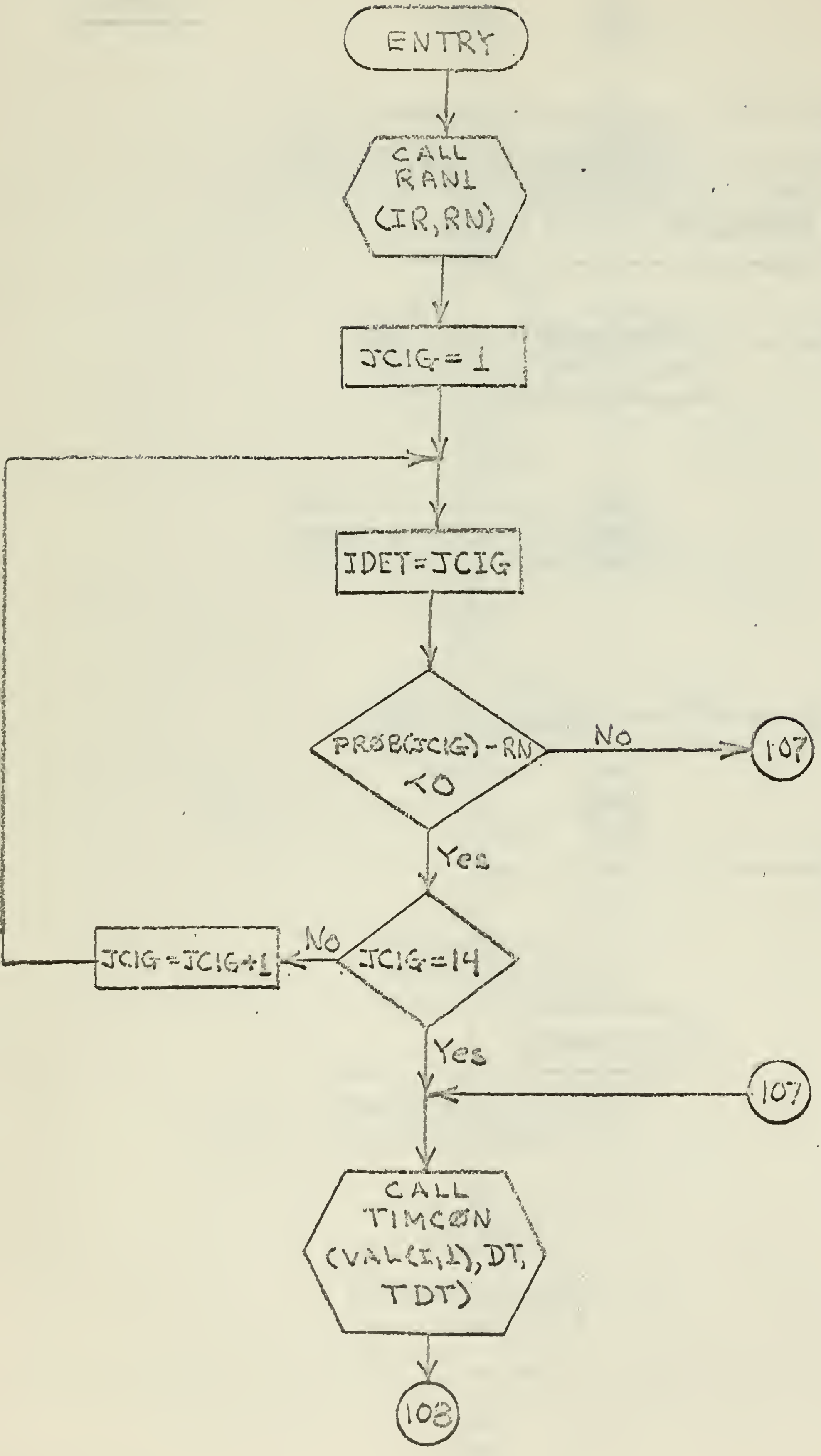

ENTRY
SDELAY=0.
LDFLAG=1
TREF=TD(MM)
NM=5*(NMIN-1)+5
M1=SULDL(L,NM)
105
CALL RAN1 (IR, RN)
SUCL(J,7)-RN <0
No
104
Yes
CALL RAN1 (IR, DELAY)
102

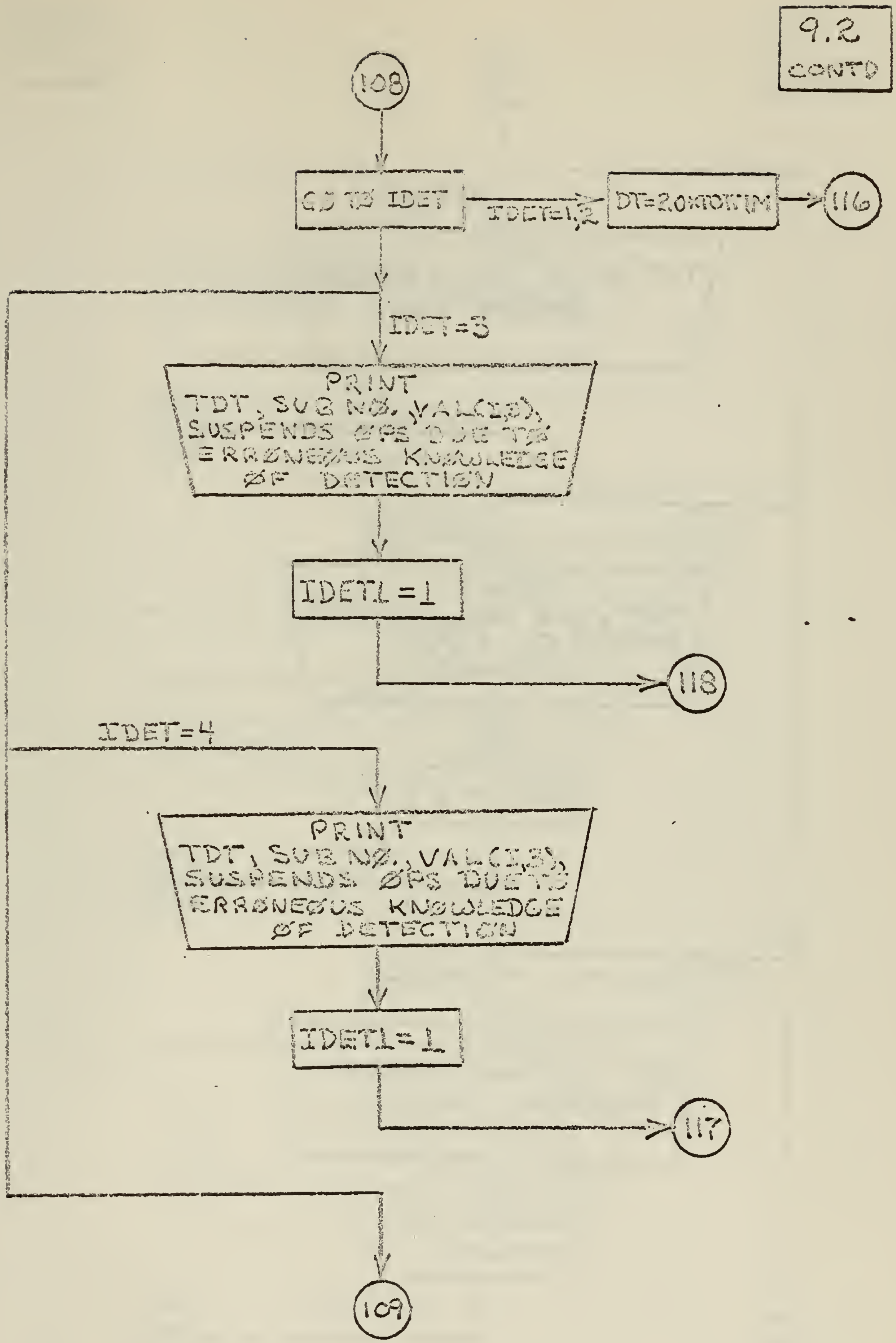
9.1 CONTD


102
SDELAY = SDELAY + DELAY
SDELAY - SDCLCTS ≤ 0
No
106
Yes
TREF = SDELAY + TD(MM)
TREF - TD(MM+1) ≥ 0
No
105
Yes
106
MR = MR + 1
SMRØB(MR) = M1
CALL TIMCØN (VAL(I,1), TREF, TLAY)
103

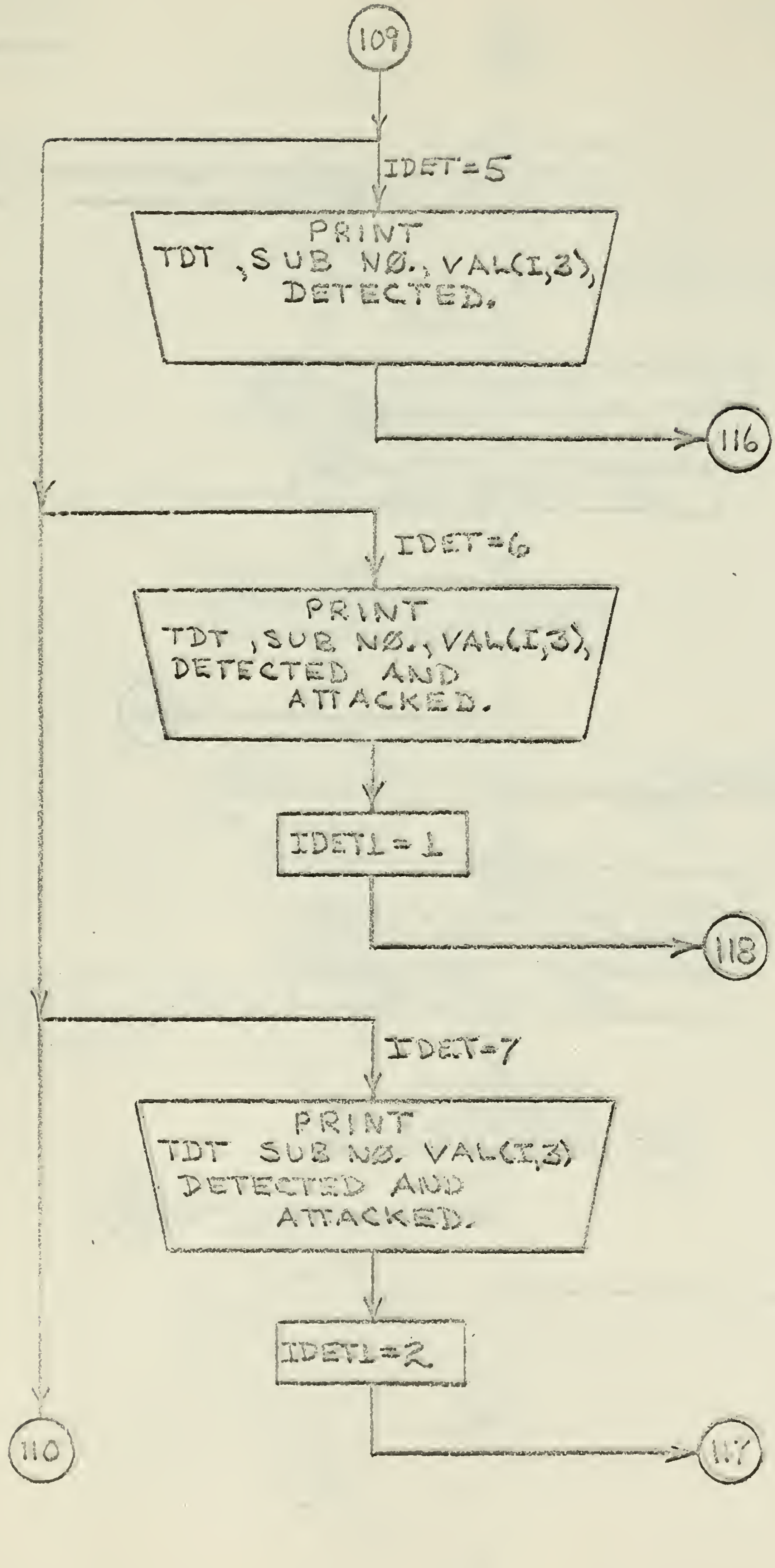

103
PRINT
NØT LAYED DUE TØ
EXCESSIVE TIME DELAY
MLFLAG=0
98
104
CØNTINUE

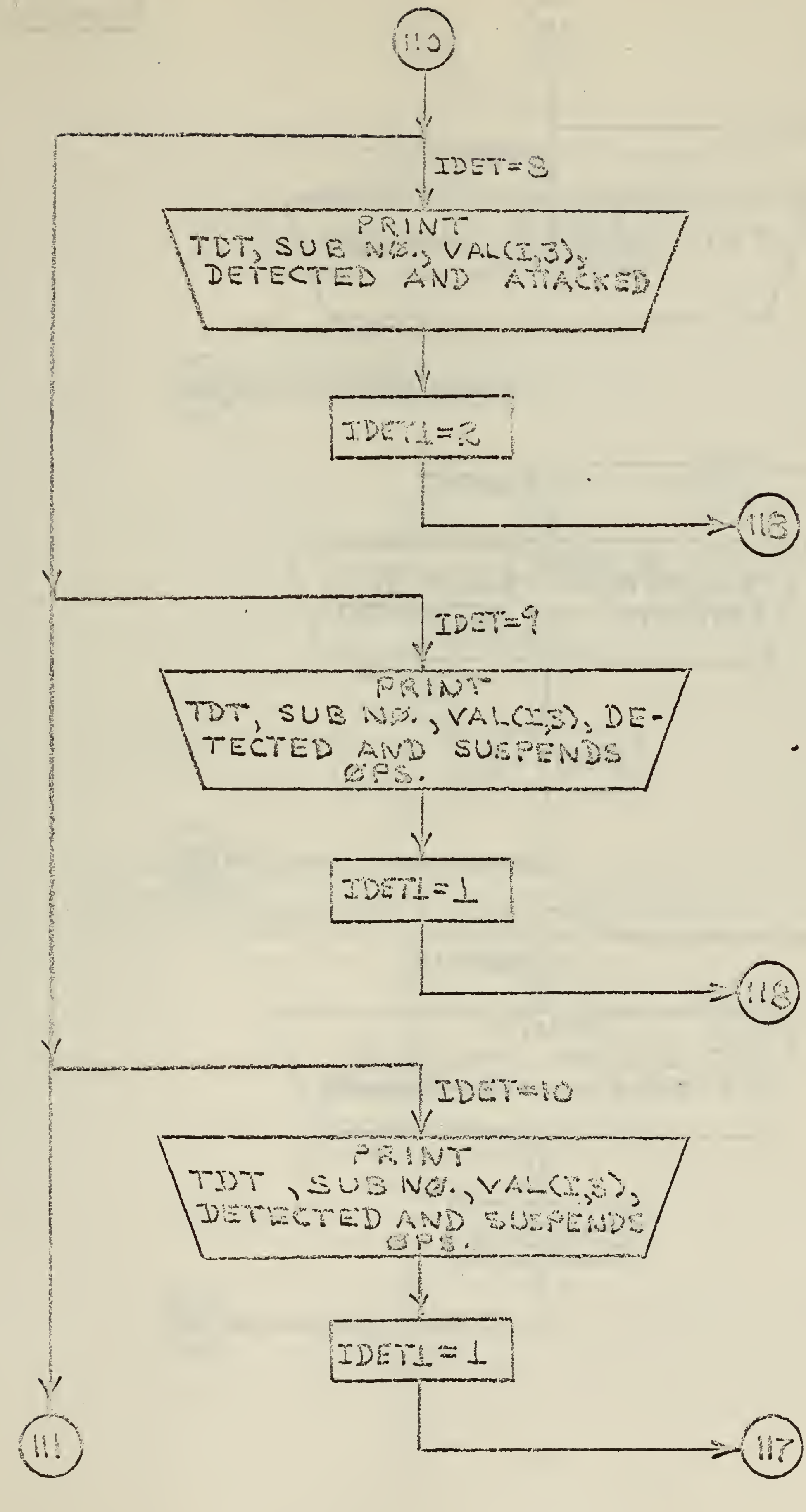
9.2

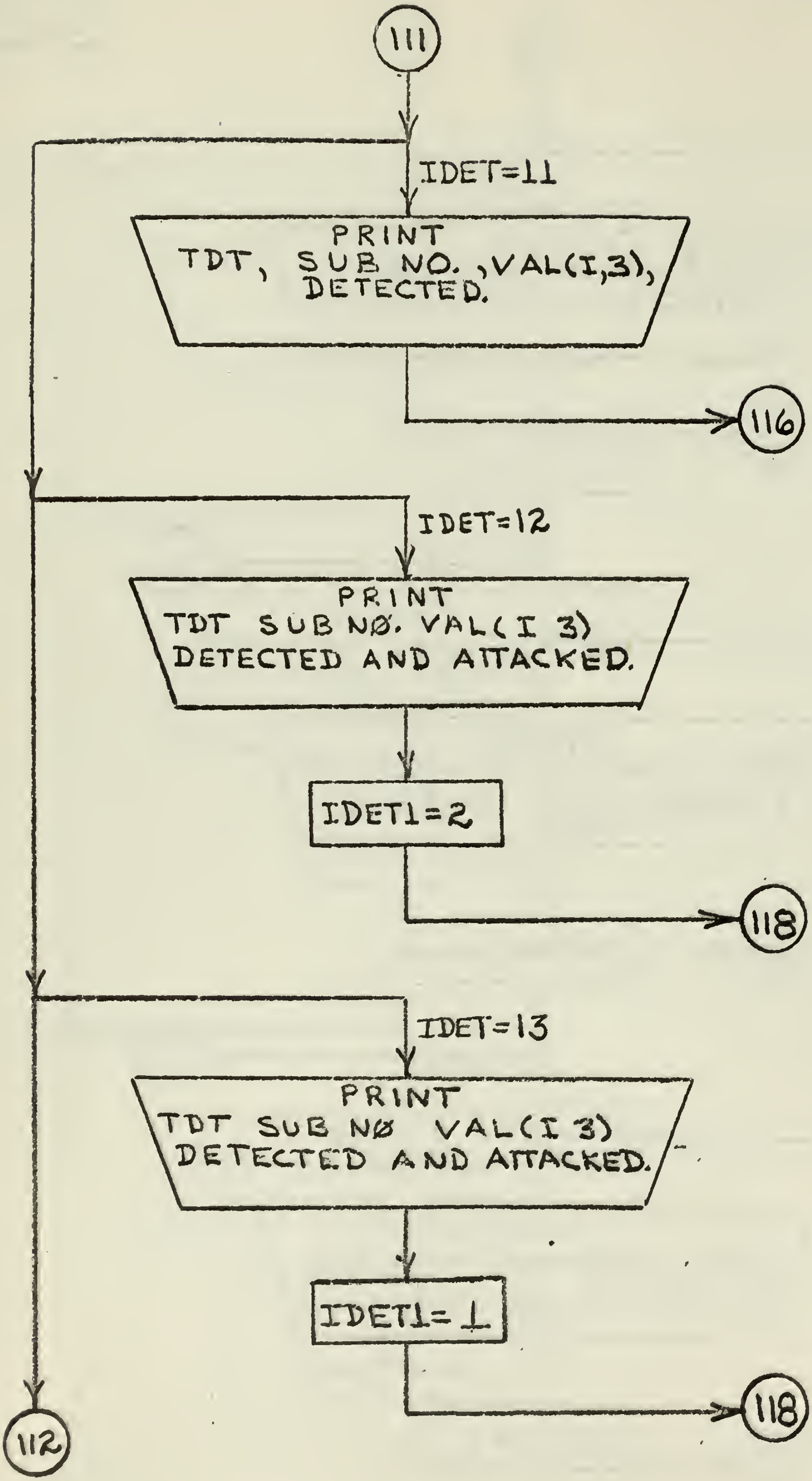

ENTRY
CALL RAN1 (IR,RN)
JCIG=1
IDET=JCIG
PRØB(JCIG)-RN <0
No
107
Yes
JCIG=14
No
JCIG=JCIG+1
Yes
107
CALL TIMCØN (VAL(I,1),DT, TDT)
108


9.2
CONTD
108
GO TØ IDET
IDET=1,2
DT=2.0XTOTTIM
116
IDET=3
PRINT
TDT, SUB NØ, VAL(I,3), SUSPENDS ØPS DUE TØ ERRØNEØUS KNØWLEDGE ØF DETECTIØN
IDETL=1
118
IDET=4
PRINT
TDT, SUB NØ, VAL(I,3), SUSPENDS ØPS DUE TØ ERRØNEØUS KNØWLEDGE ØF DETECTIØN
IDETL=1
117
109

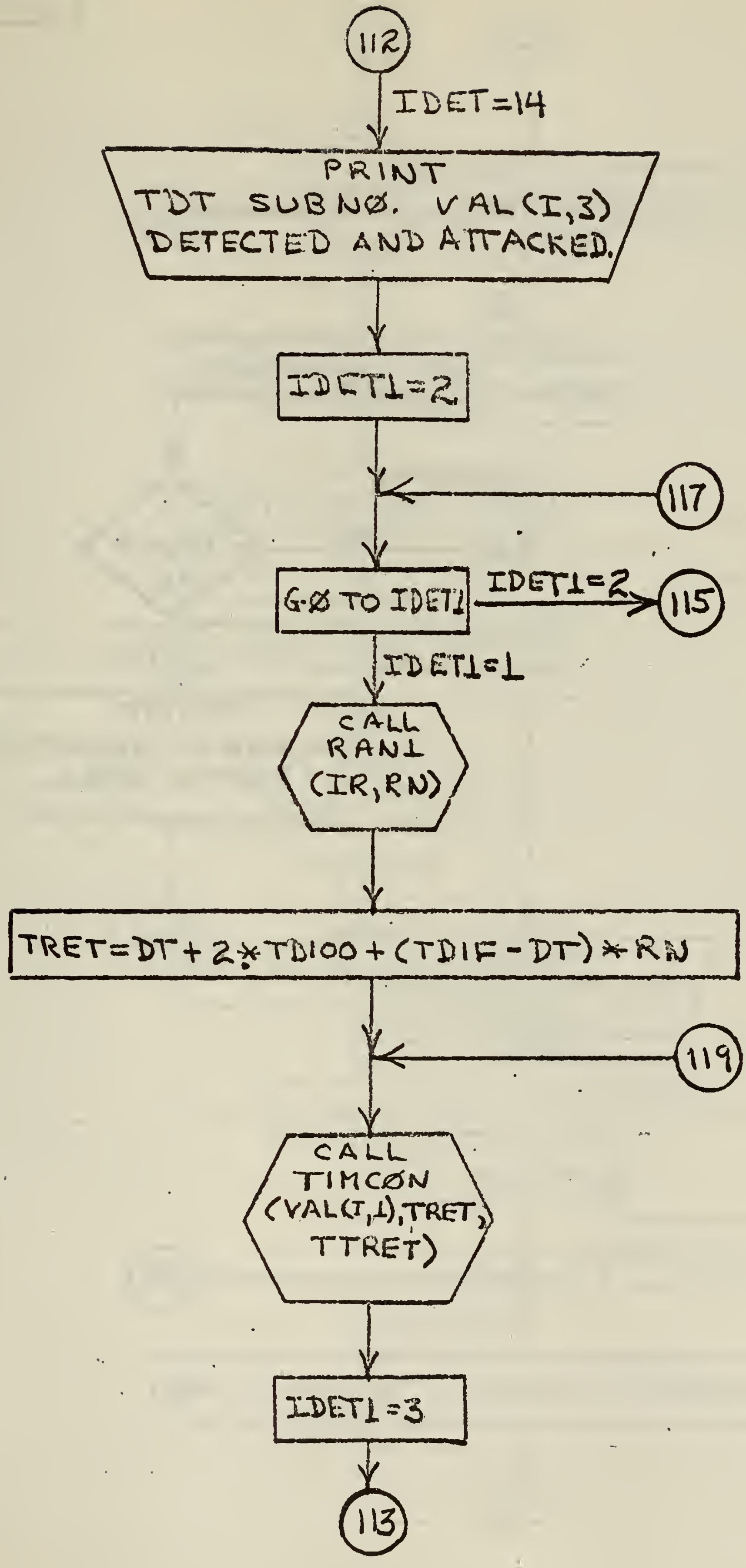
9.2 CONTD

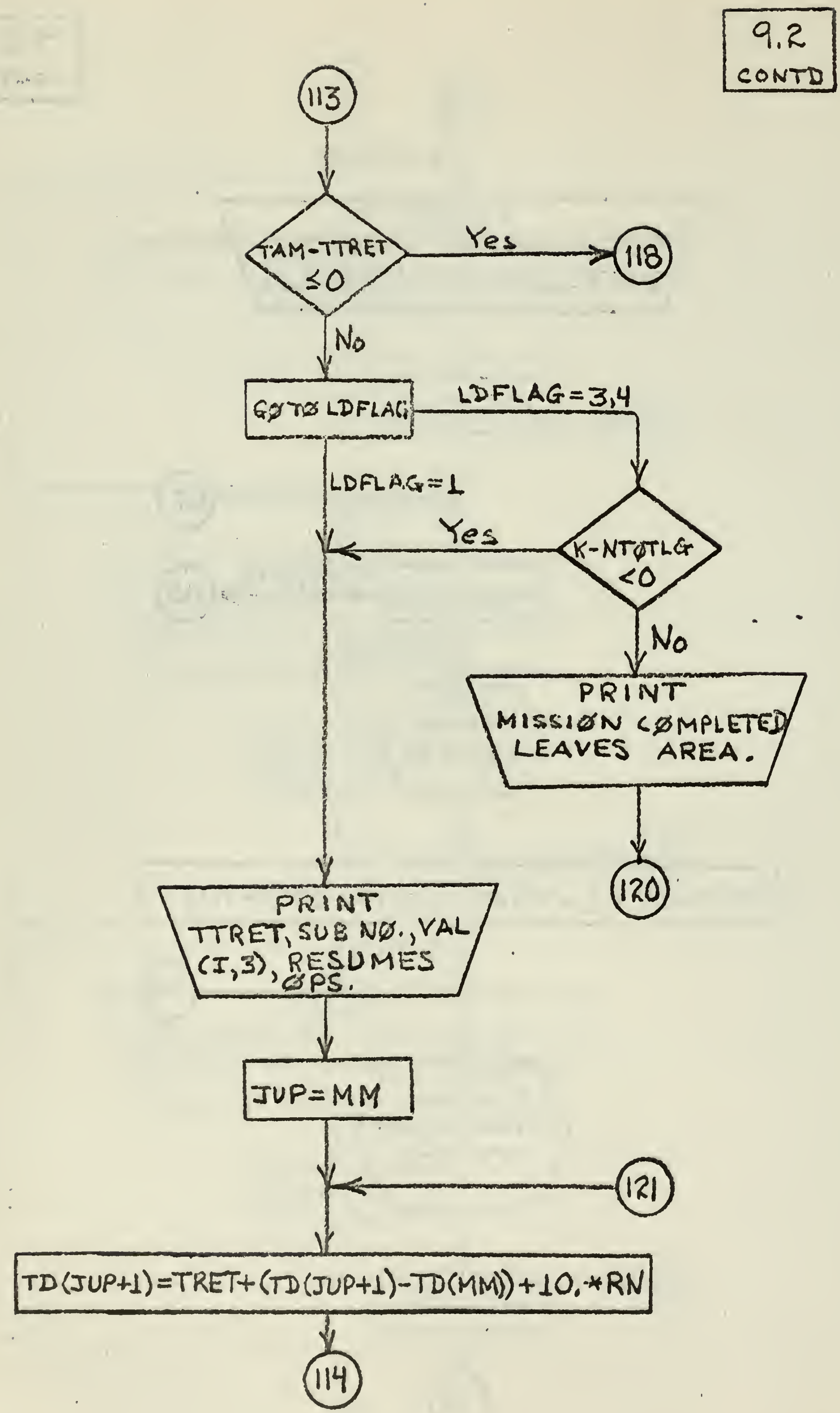

109
IDET=5
PRINT
TDT ,SUB NØ., VAL(I,3),
DETECTED.
116
IDET=6
PRINT
TDT ,SUB NØ., VAL(I,3),
DETECTED AND
ATTACKED.
IDET1 = 1
118
IDET=7
PRINT
TDT SUB NØ. VAL(I,3)
DETECTED AND
ATTACKED.
IDET1=2
110
117

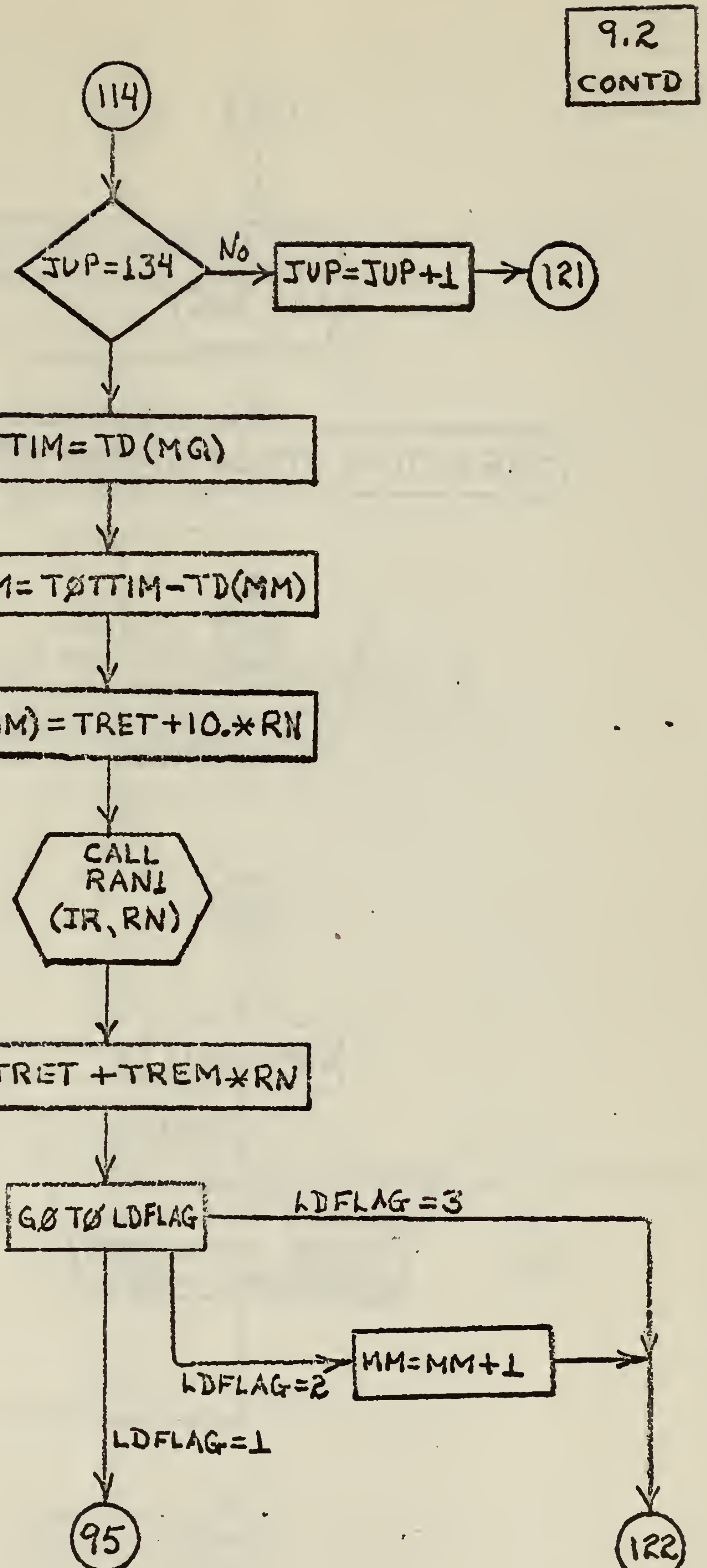

110
IDET=8
PRINT
TDT, SUB NØ., VAL(I,3), DETECTED AND ATTACKED
IDET1=2
118
IDET=9
PRINT
TDT, SUB NØ., VAL(I,3), DE-TECTED AND SUSPENDS ØPS.
IDET1=1
118
IDET=10
PRINT
TDT, SUB NØ., VAL(I,3), DETECTED AND SUSPENDS ØPS.
IDET1=1
111
117

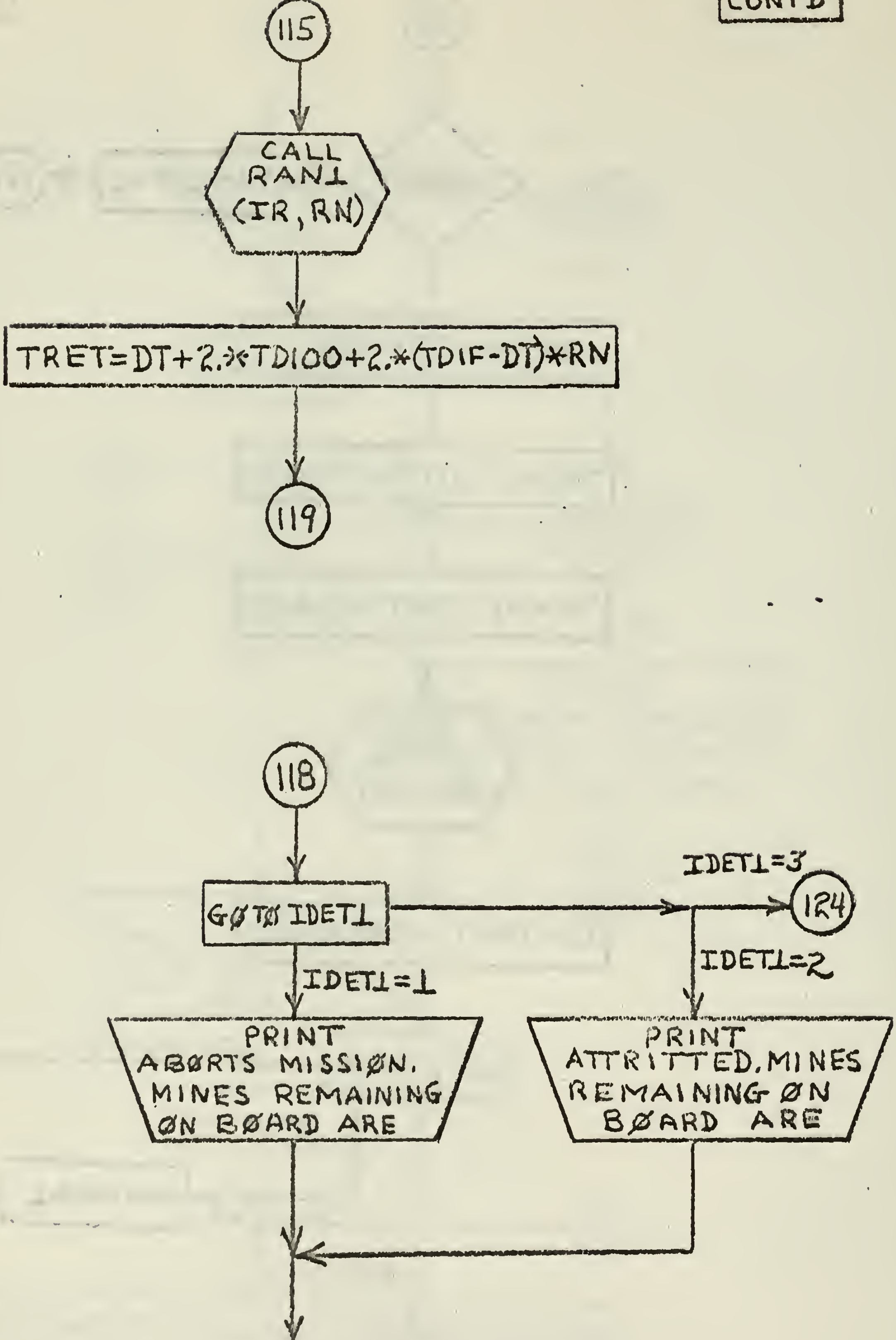

111
IDET=11
PRINT
TDT, SUB NO. ,VAL(I,3),
DETECTED.
116
IDET=12
PRINT
TDT SUB NØ. VAL(I 3)
DETECTED AND ATTACKED.
IDET1=2
118
IDET=13
PRINT
TDT SUB NØ VAL(I 3)
DETECTED AND ATTACKED.
IDET1=1
118
112

9.2 CONTD

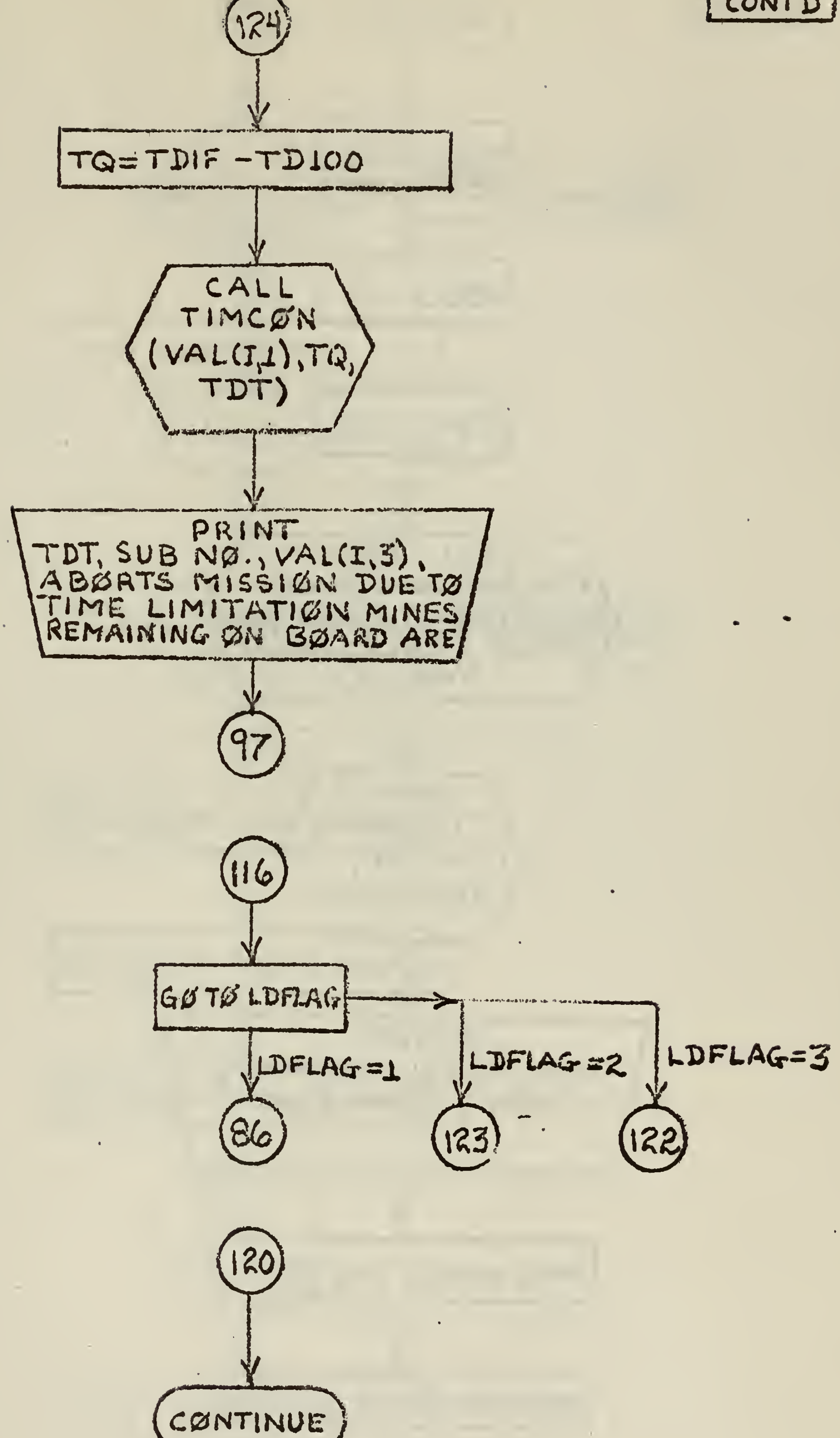

112
IDET=14
PRINT
TDT SUBNØ. VAL(I,3)
DETECTED AND ATTACKED.
IDET1=2
117
GØ TO IDET1
IDET1=2
115
IDET1=1
CALL
RAN1
(IR,RN)
TRET=DT+2*TD100+(TDIF-DT)*RN
119
CALL
TIMCØN
(VAL(I,1),TRET,
TTRET)
IDET1=3
113

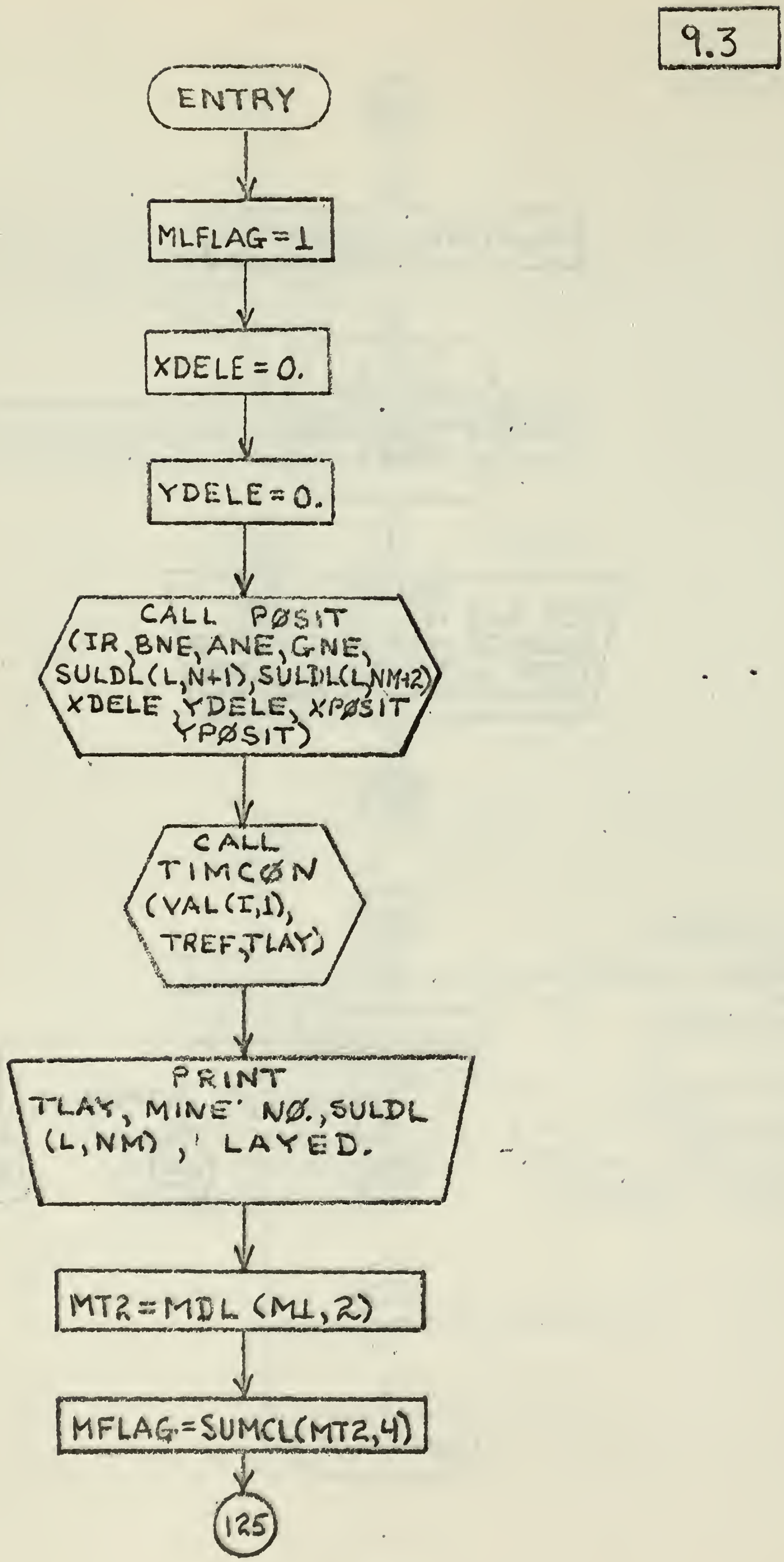

9.2
CONTD
113
TAM-TTRET ≤0
Yes
118
No
GØTØ LDFLAG
LDFLAG=3,4
LDFLAG=1
Yes
K-NTØTLG <0
No
PRINT
MISSIØN CØMPLETED
LEAVES AREA.
120
PRINT
TTRET, SUB NØ., VAL (I,3), RESUMES ØPS.
JUP=MM
121
TD(JUP+1)=TRET+(TD(JUP+1)-TD(MM))+10.*RN
114

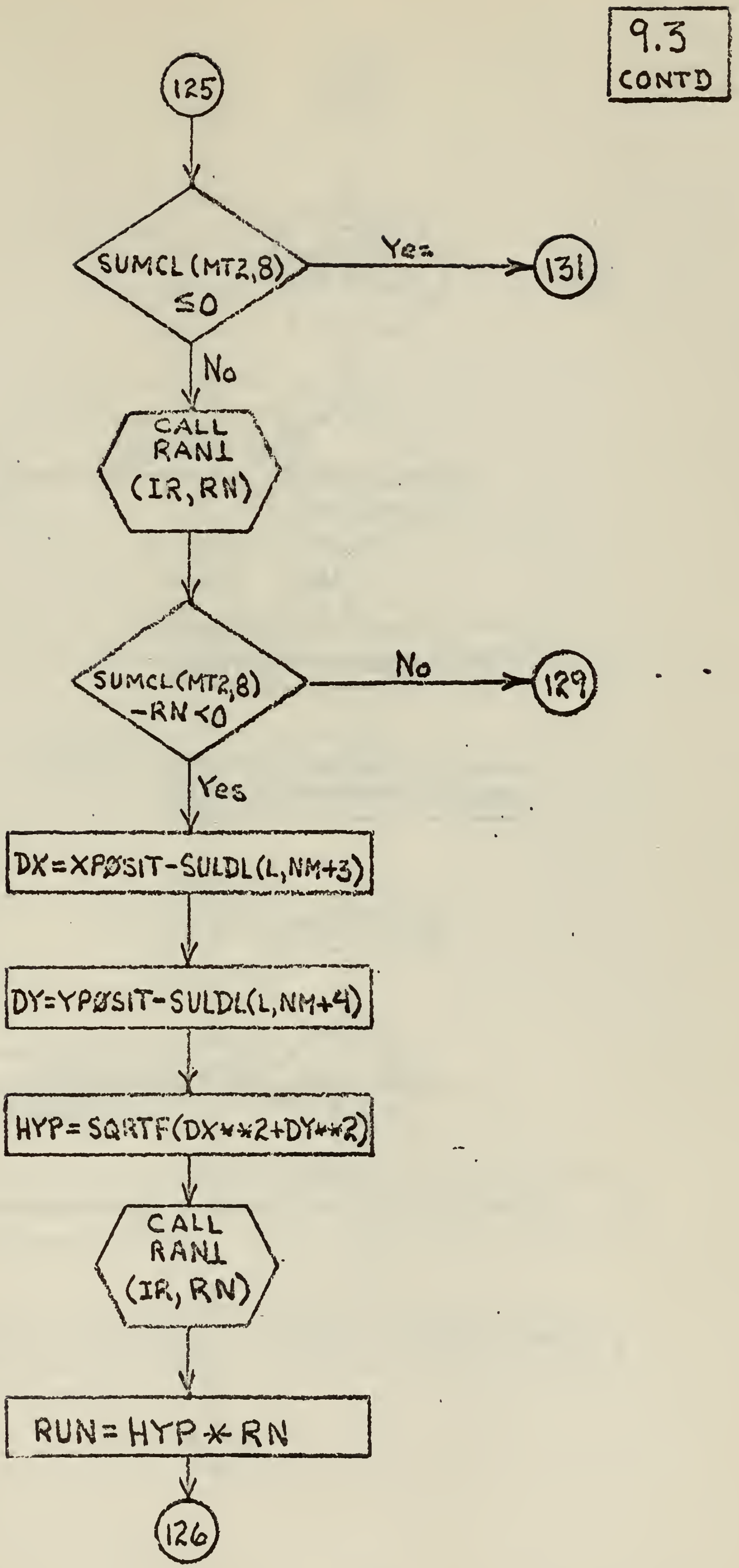

9.2
CONTD
114
JUP=134
No
JUP=JUP+1
121
TØTTIM=TD(MG)
TREM=TØTTIM-TD(MM)
TD(MM)=TRET+10.*RN
CALL
RAN1
(IR, RN)
DT=TRET +TREM*RN
GØ TØ LDFLAG
LDFLAG=3
LDFLAG=2
MM=MM+1
LDFLAG=1
95
122


115
CALL RAN1 (IR, RN)
TRET=DT+2.*TD100+2.*(TDIF-DT)*RN
119
118
GØTØ IDET1
IDET1=3
124
IDET1=1
IDET1=2
PRINT ABØRTS MISSIØN. MINES REMAINING ØN BØARD ARE
PRINT ATTRITTED. MINES REMAINING ØN BØARD ARE
97

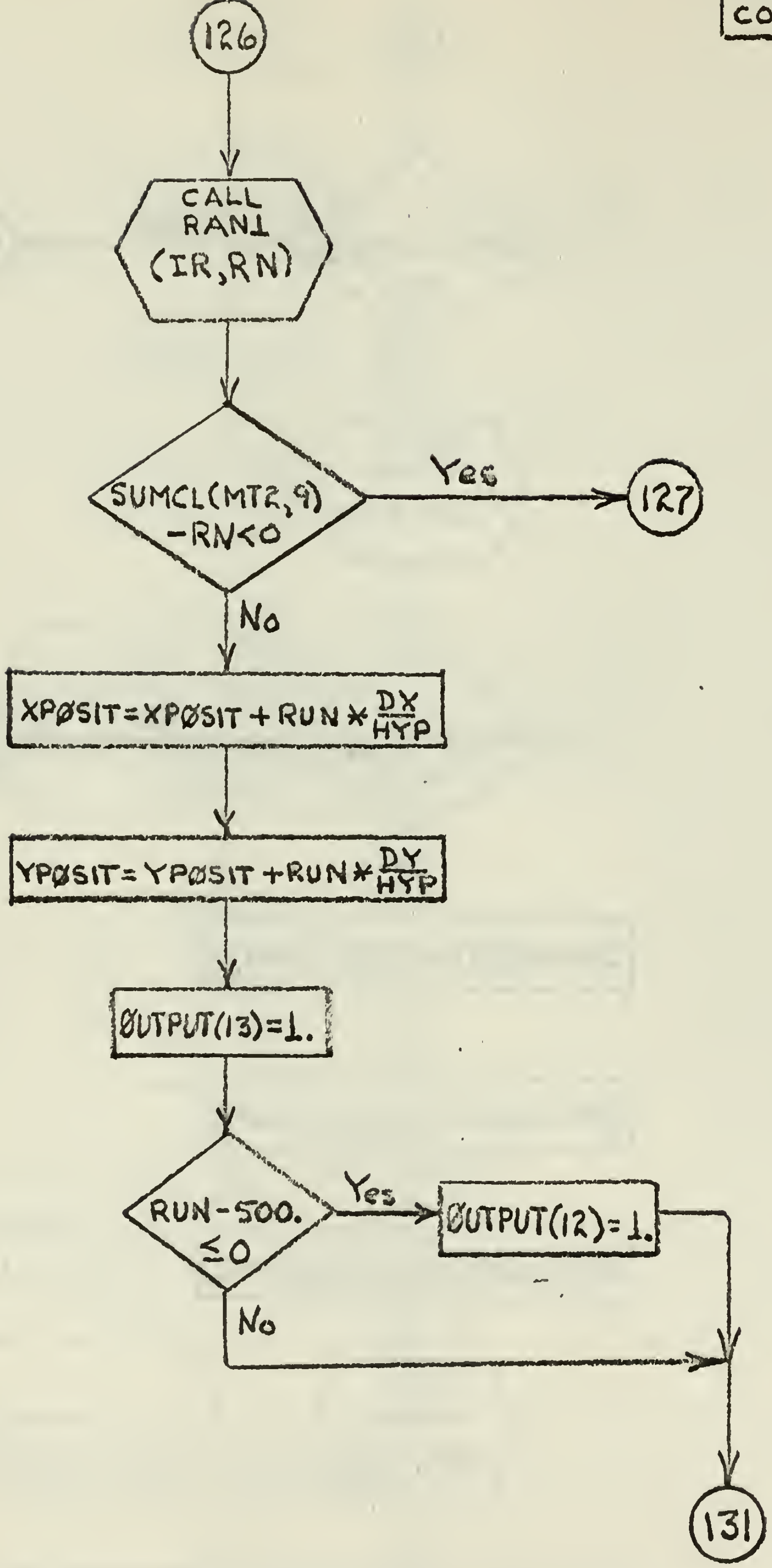
9.2
CONTD


124
TQ=TDIF -TD100
CALL TIMCØN (VAL(I,1),TQ, TDT)
PRINT TDT, SUB NØ., VAL(I,3), ABØRTS MISSIØN DUE TØ TIME LIMITATIØN MINES REMAINING ØN BØARD ARE
97
116
GØ TØ LDFLAG
LDFLAG=1
LDFLAG=2
LDFLAG=3
86
123
122
120
CØNTINUE

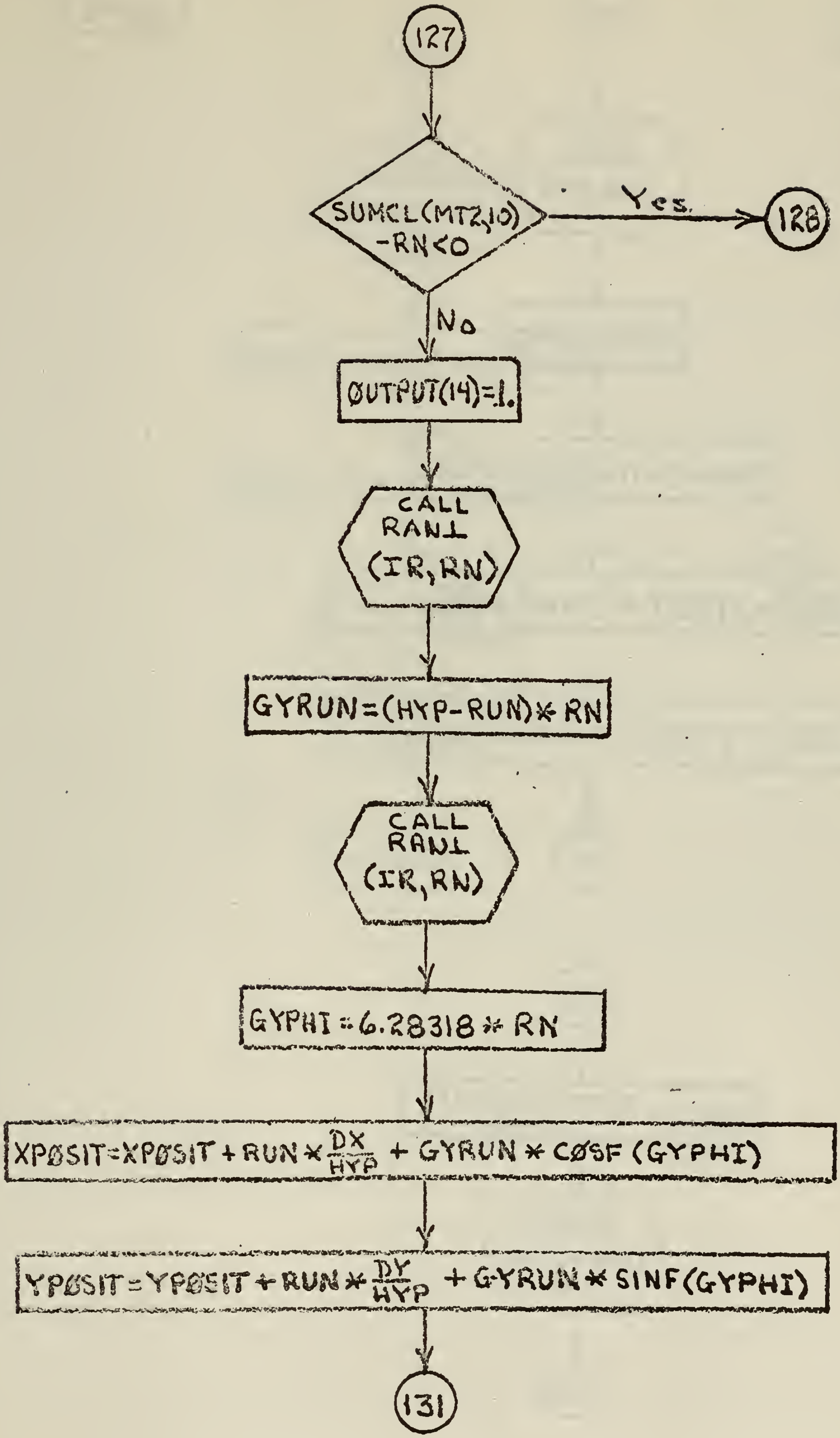

9.3
ENTRY
MLFLAG=1
XDELE=0.
YDELE=0.
CALL PØSIT (IR, BNE, ANE, GNE, SULDL(L,N+1), SULDL(L,NM+2) XDELE, YDELE, XPØSIT YPØSIT)
CALL TIMCØN (VAL(I,1), TREF, TLAY)
PRINT TLAY, MINE' NØ., SULDL (L,NM), ' LAYED.
MT2=MDL (M1, 2)
MFLAG=SUMCL(MT2,4)
125


9.3
CONTD
125
SUMCL (MT2,8) ≤0
Yes
131
No
CALL RAN1 (IR, RN)
SUMCL(MT2,8) -RN<0
No
129
Yes
DX=XPØSIT-SULDL(L,NM+3)
DY=YPØSIT-SULDL(L,NM+4)
HYP= SQRTF(DX**2+DY**2)
CALL RAN1 (IR, RN)
RUN= HYP * RN
126

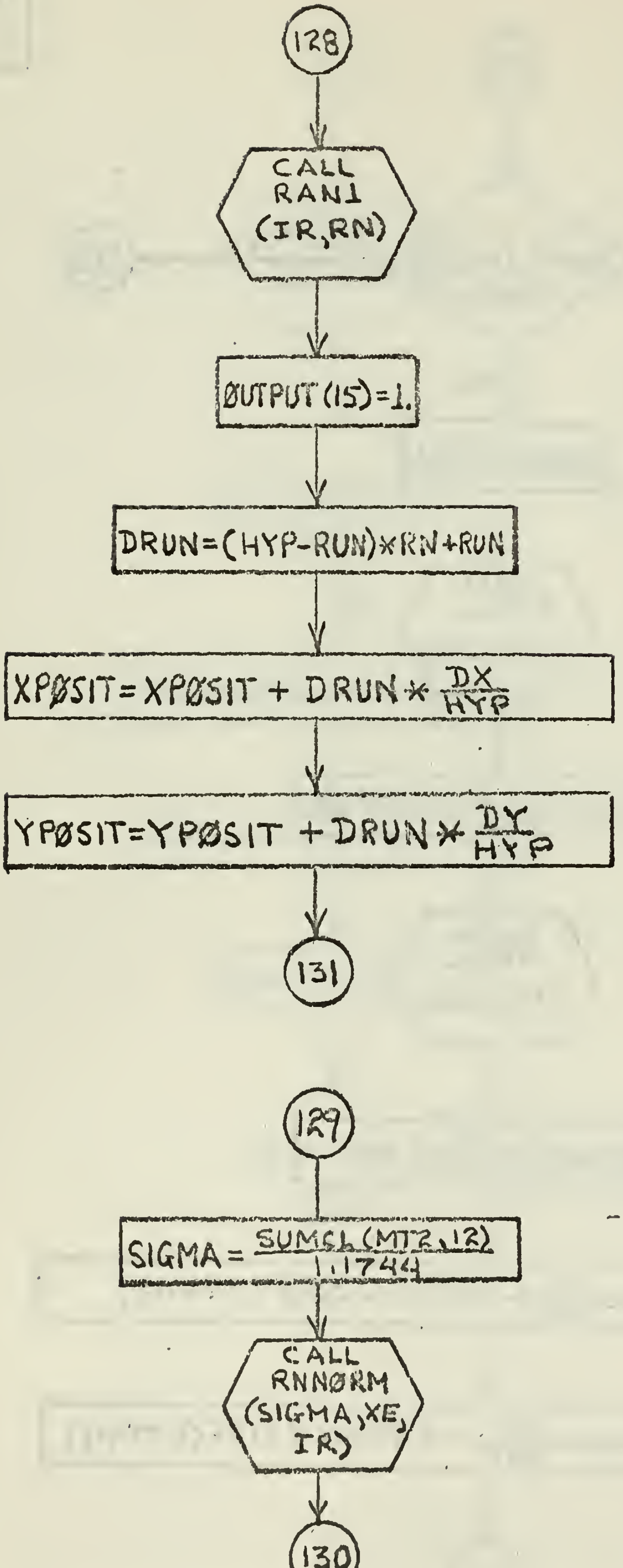
9.3 CONTD


126
CALL RAN1 (IR,RN)
SUMCL(MT2,9) -RN<0
Yes
127
No
XPØSIT=XPØSIT+RUN*DX/HYP
YPØSIT=YPØSIT+RUN*DY/HYP
ØUTPUT(13)=1.
RUN-500. ≤0
Yes
ØUTPUT(12)=1.
No
131

9.3 CONTD

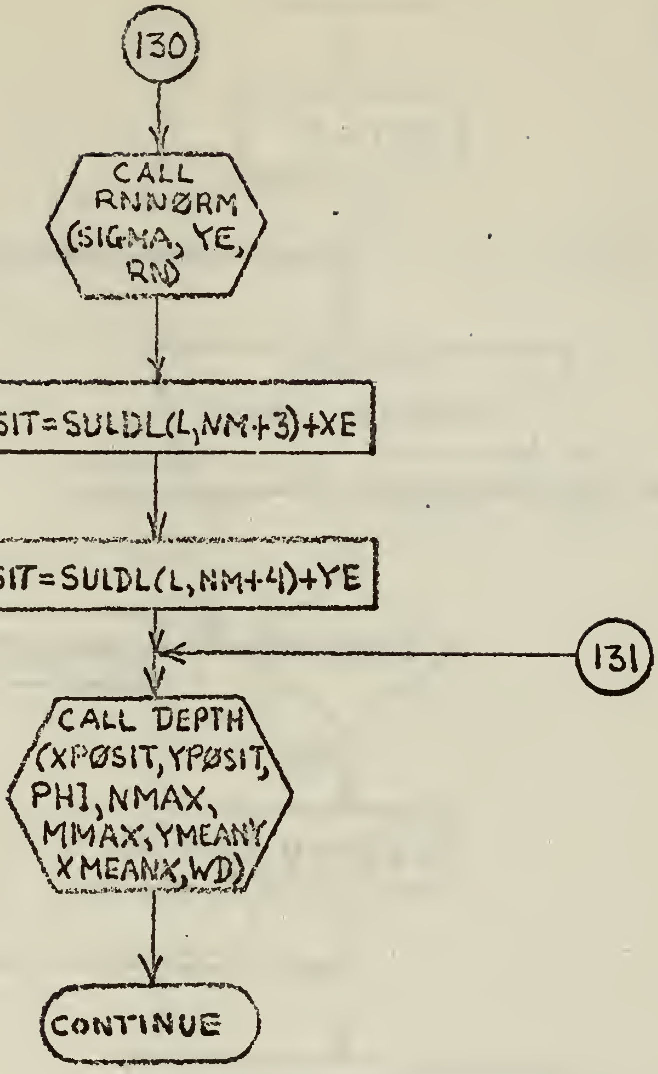

127
SUMCL(MTZ,10) -RN<0
Yes
128
No
ØUTPUT(14)=1.
CALL RAN1 (IR,RN)
GYRUN=(HYP-RUN)*RN
CALL RAN1 (IR,RN)
GYPHI=6.28318*RN
XPØSIT=XPØSIT+RUN*DX/HYP+GYRUN*CØSF(GYPHI)
YPØSIT=YPØSIT+RUN*DY/HYP+GYRUN*SINF(GYPHI)
131

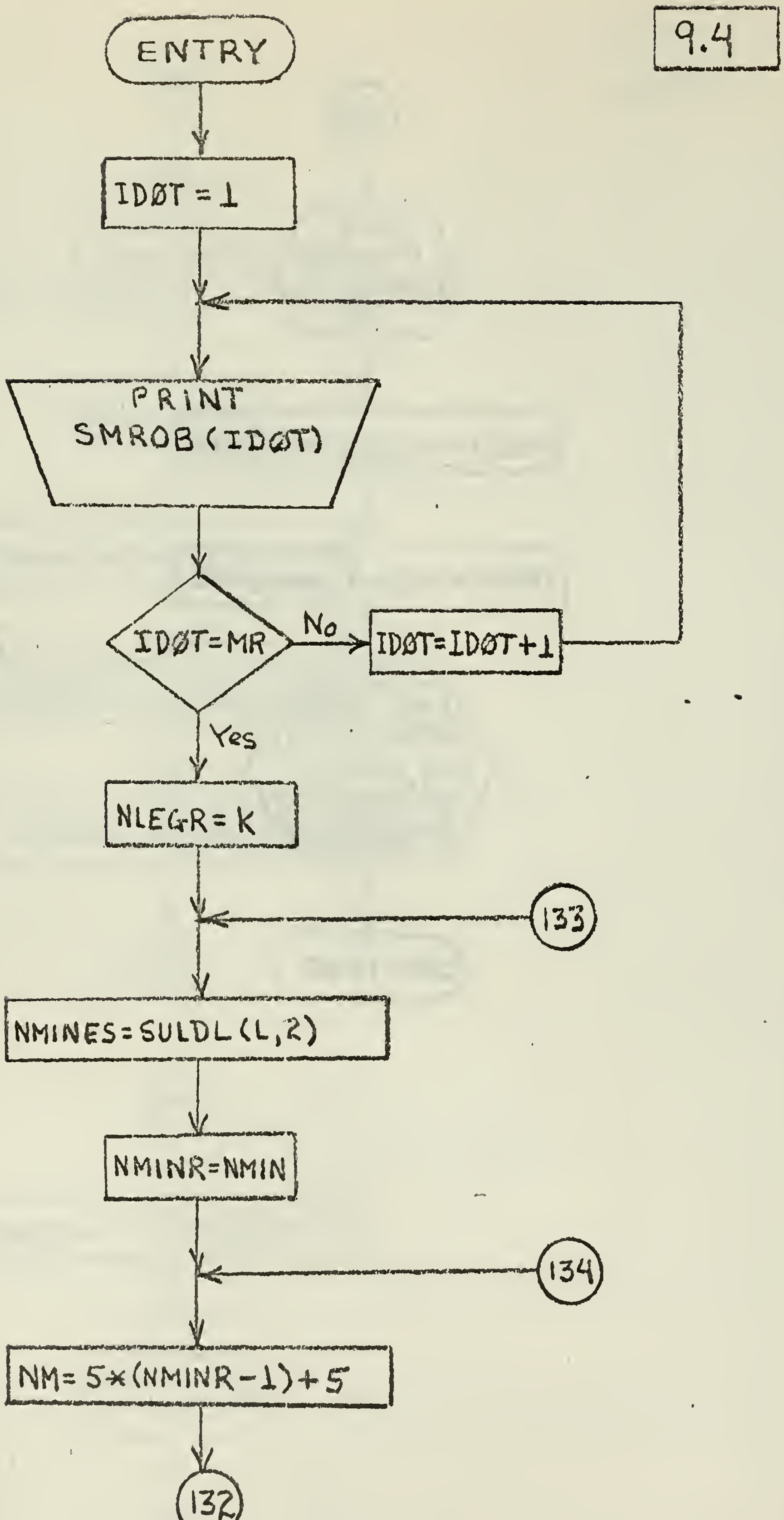
9.3 CONTD



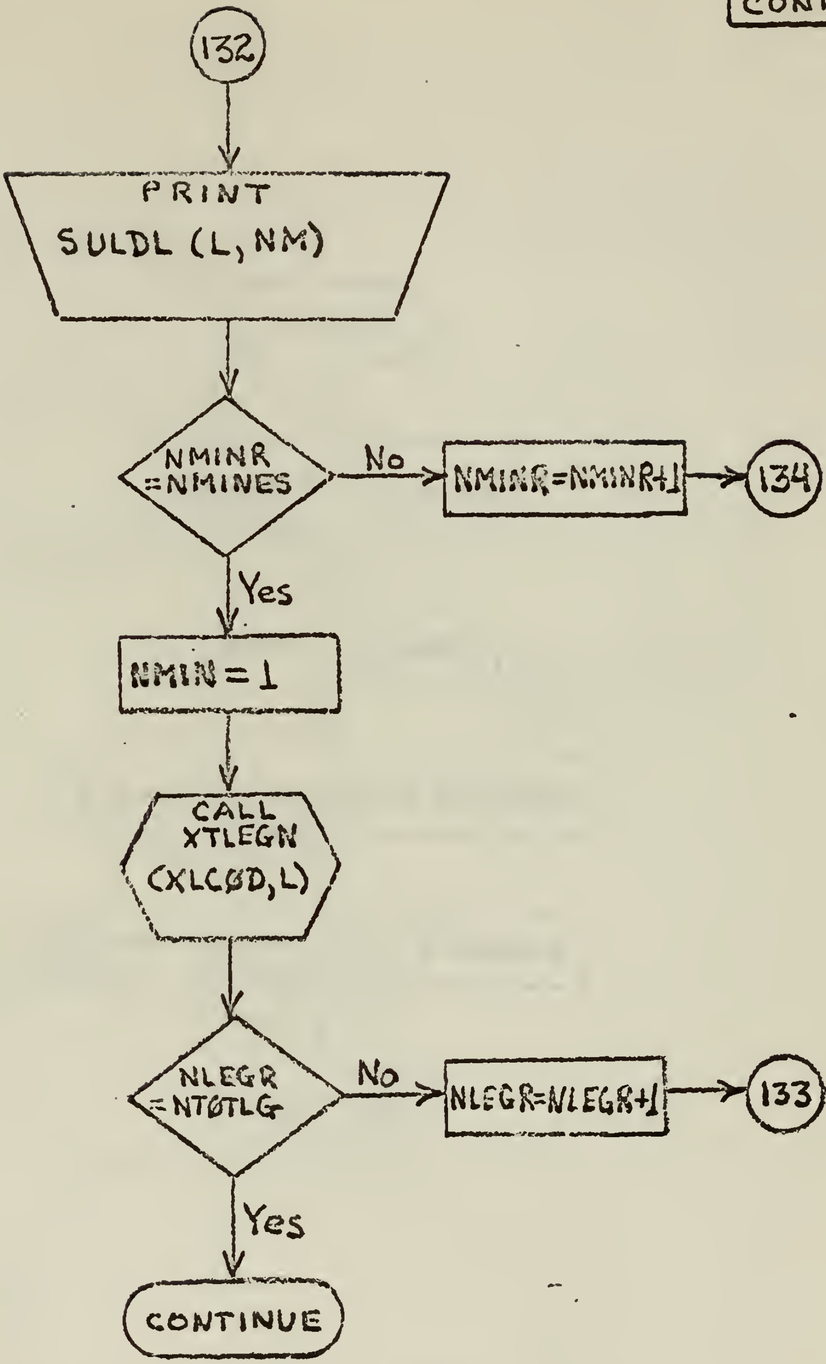
128
CALL RAN1 (IR,RN)
ØUTPUT(15)=1.
DRUN=(HYP-RUN)*RN+RUN
XPØSIT=XPØSIT + DRUN * DX/HYP
YPØSIT=YPØSIT + DRUN * DY/HYP
131
129
SIGMA = SUMCL(MT2,12)/1.1744
CALL RNNØRM (SIGMA,XE,IR)
130

9.3 CONTD

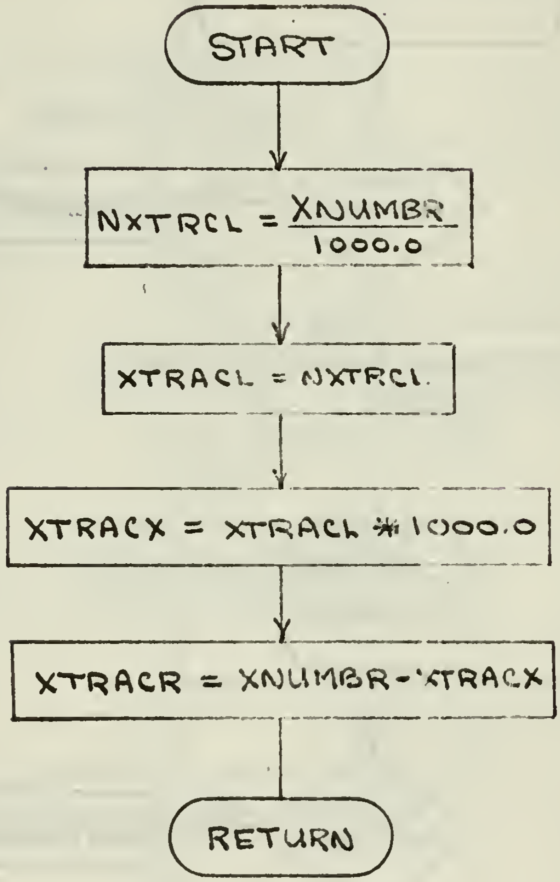

130
CALL RNNØRM (SIGMA, YE, RN)
XPØSIT=SULDL(L,NM+3)+XE
YPØSIT=SULDL(L,NM+4)+YE
131
CALL DEPTH (XPØSIT, YPØSIT, PHI, NMAX, MMAX, YMEANY, XMEANX, WD)
CONTINUE


9.4
ENTRY
IDØT = 1
PRINT
SMROB (IDØT)
IDØT=MR
No
IDØT=IDØT+1
Yes
NLEGR= K
133
NMINES = SULDL (L,2)
NMINR=NMIN
134
NM= 5*(NMINR-1)+5
132

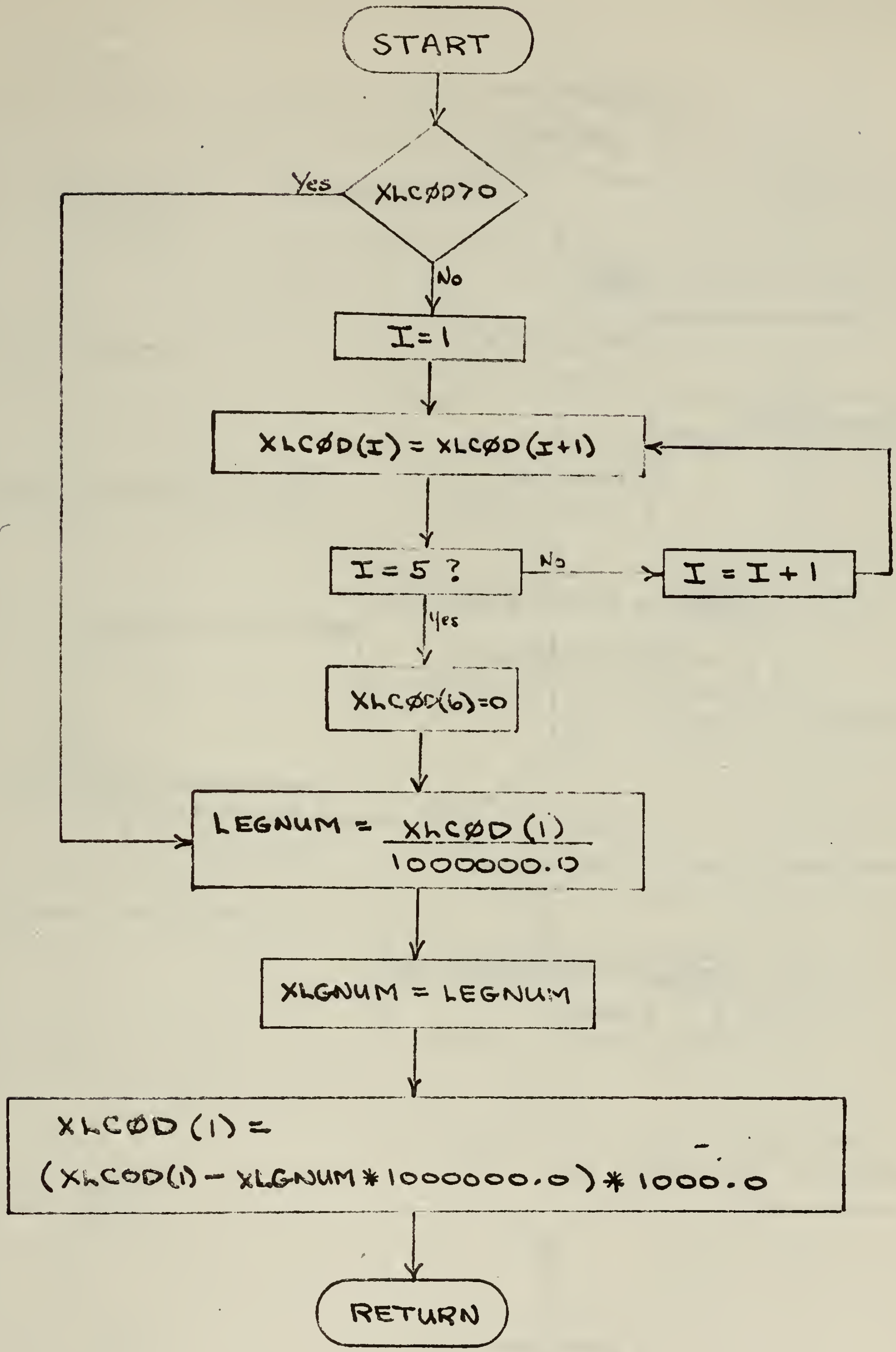
9.4 CONTD


132
PRINT
SULDL (L, NM)
NMINR =NMINES
No
NMINR=NMINR+1
134
Yes
NMIN = 1
CALL XTLEGN (XLCØD, L)
NLEGR =NTØTLG
No
NLEGR=NLEGR+1
133
Yes
CONTINUE

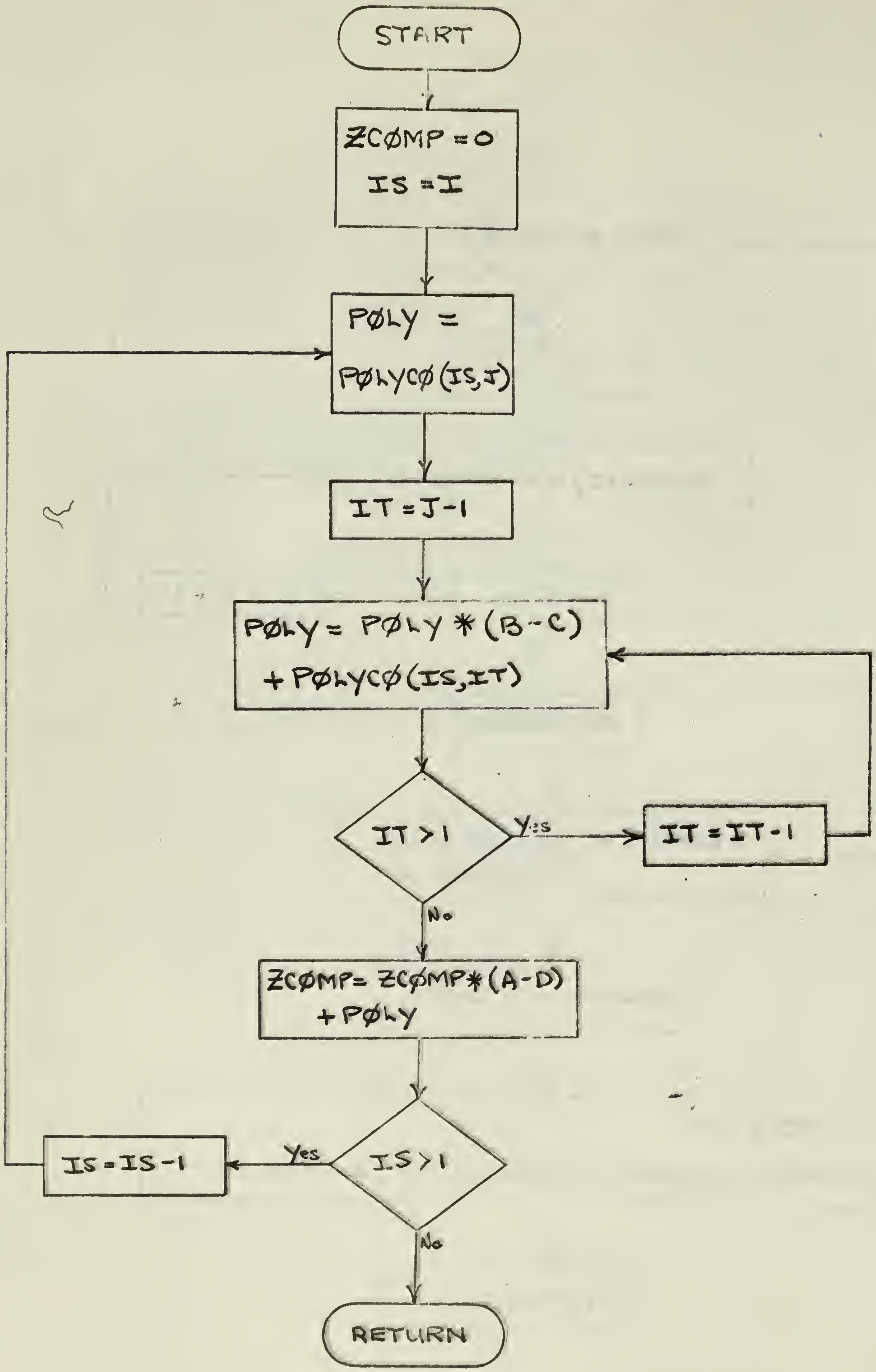
SUBROUTINE XTRACT



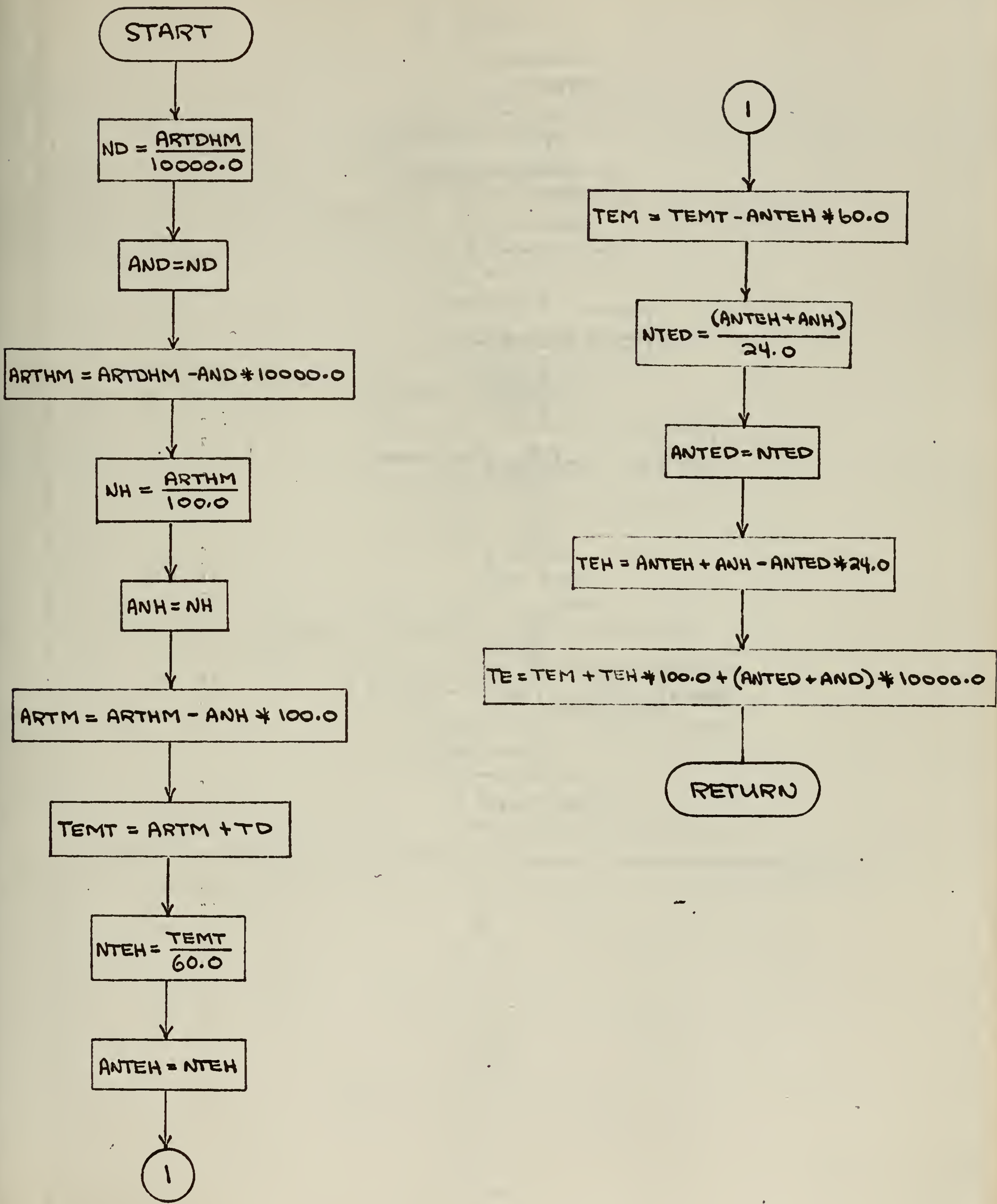
SUBRØUTINE XTLEGN



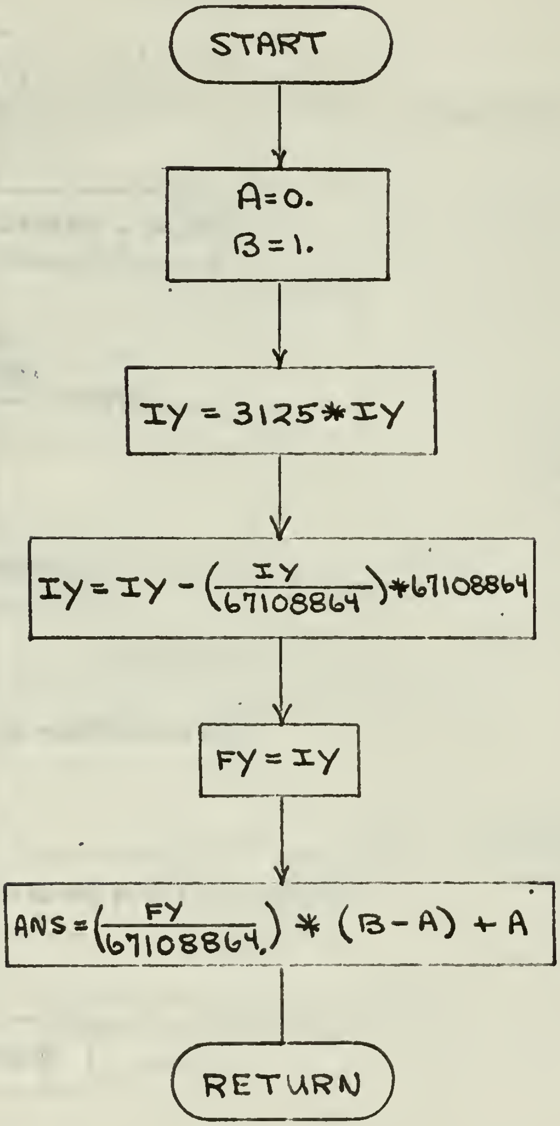
SUBRØUTINE DEPTH



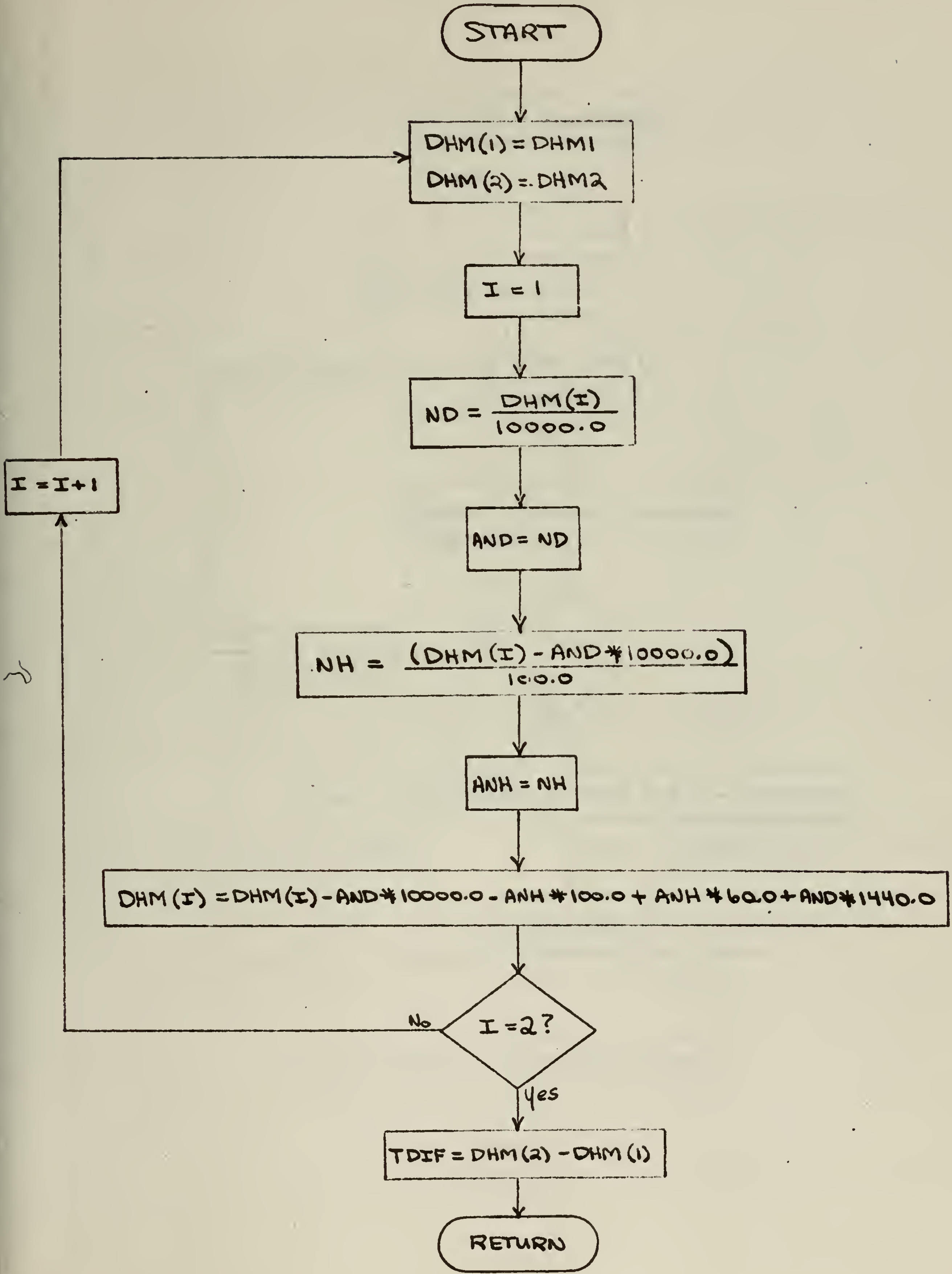
SUBRØUTINE TIMCØN



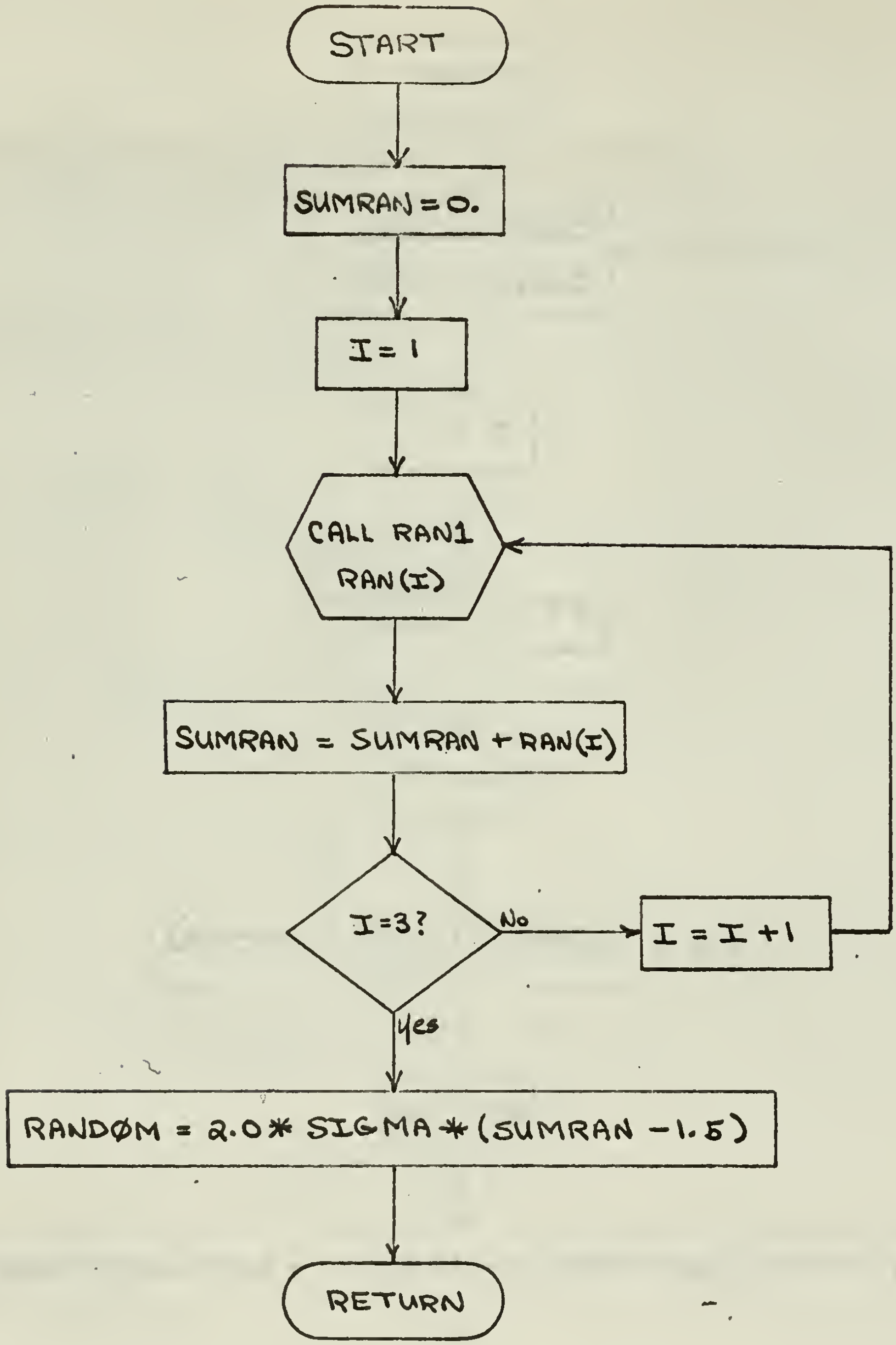
SUBRØUTINE RAN1



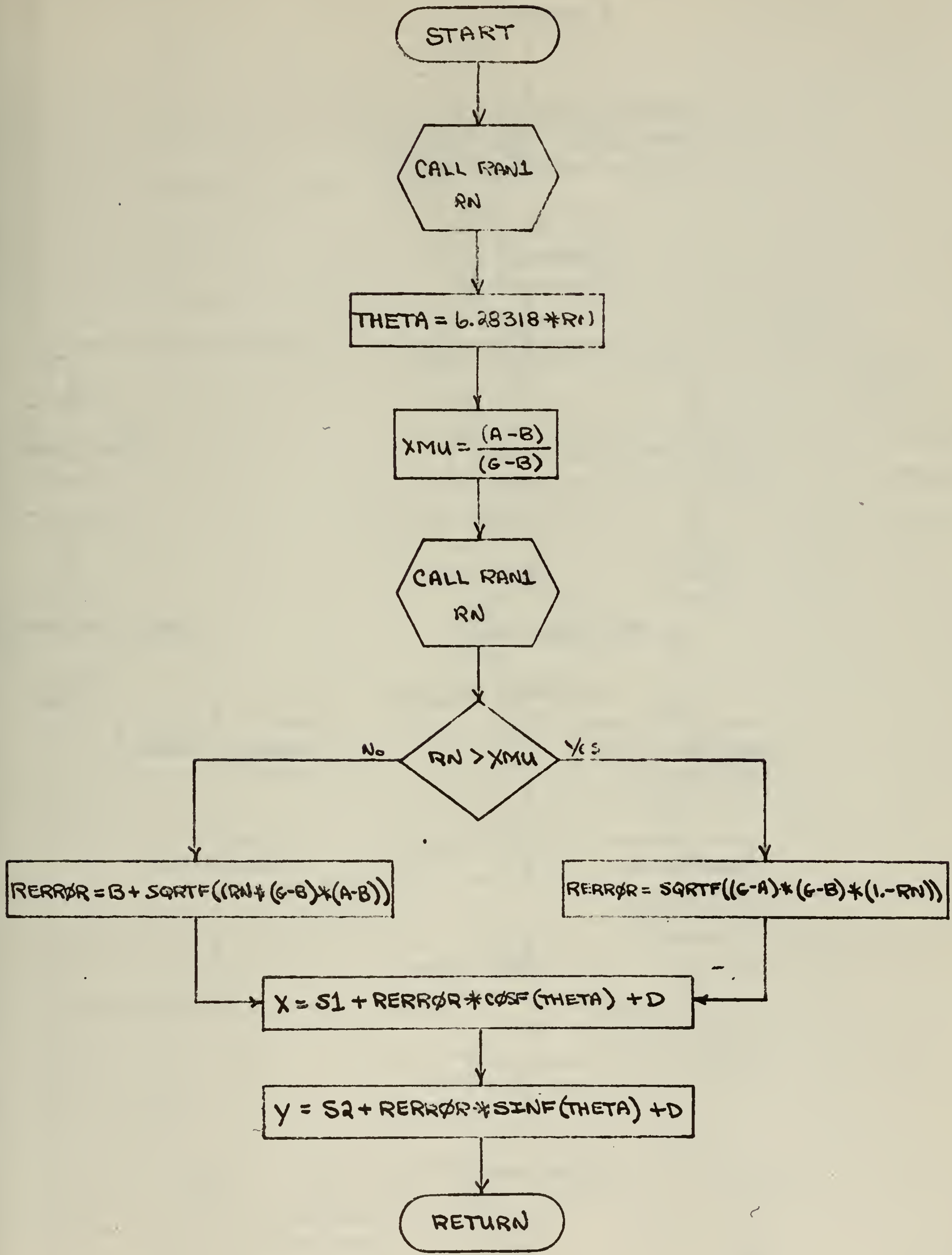
SUBRØUTINE TIMDIF



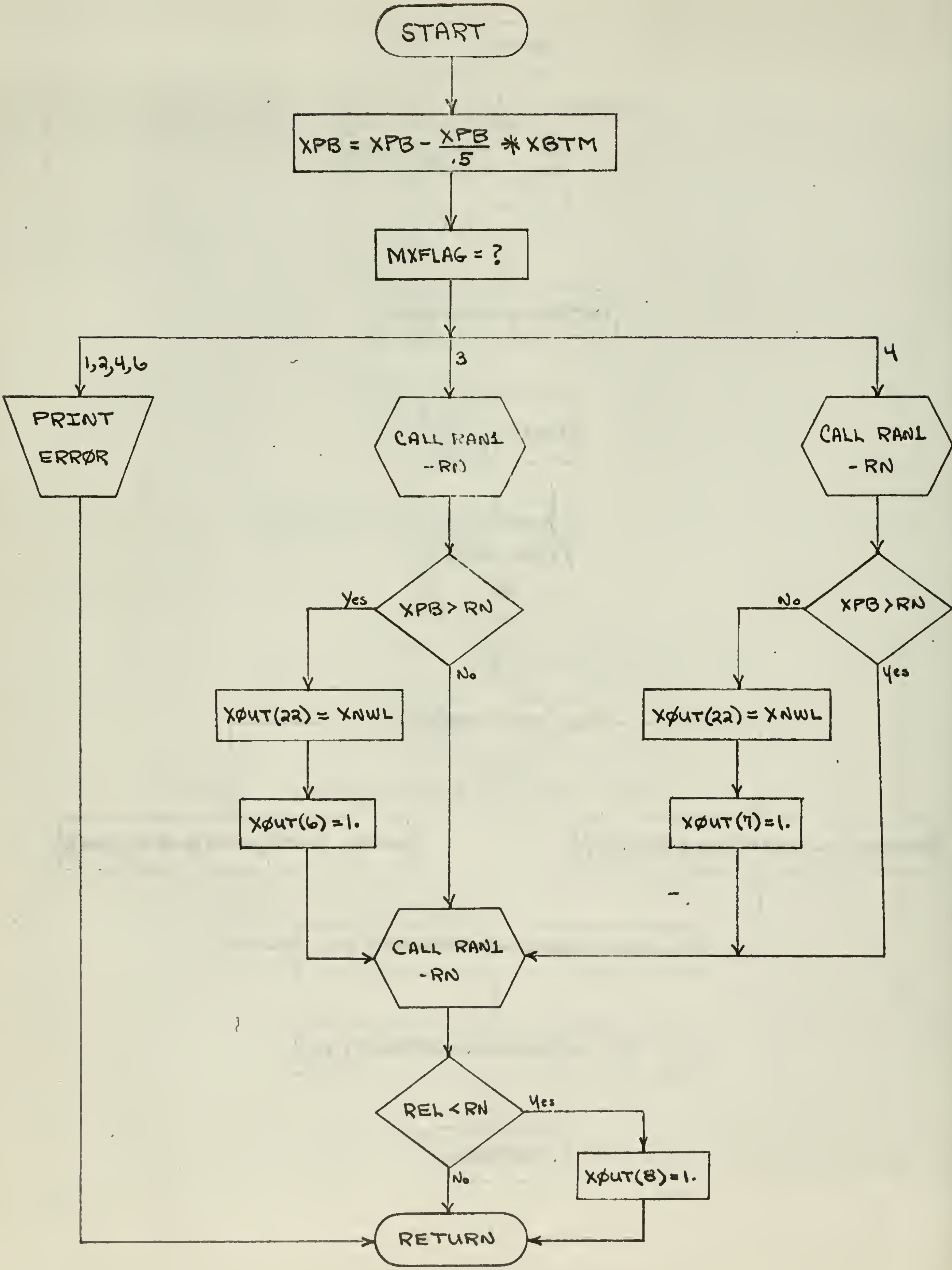
SUBRØUTINE RNORM



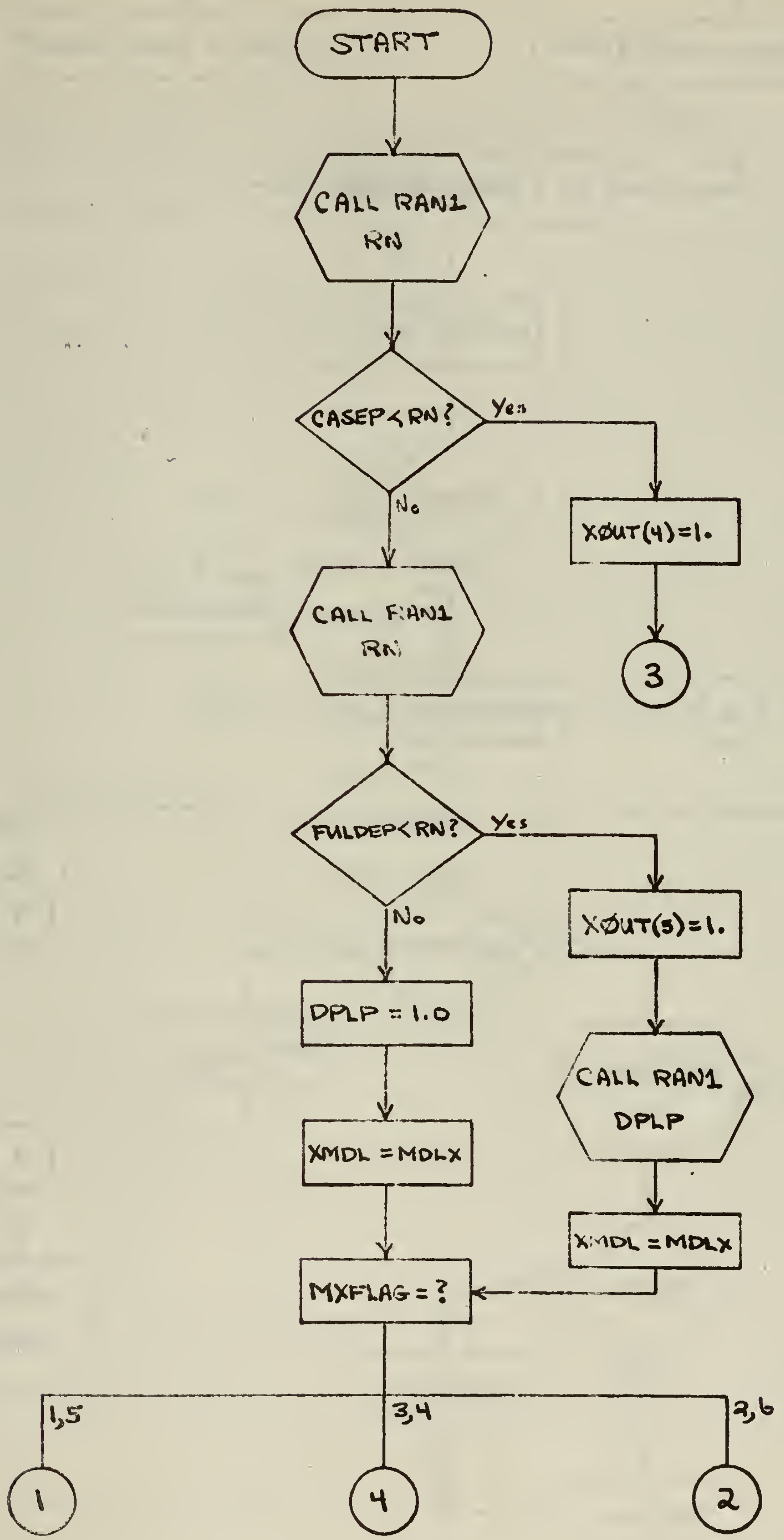
SUBRØUTINE PØSIT

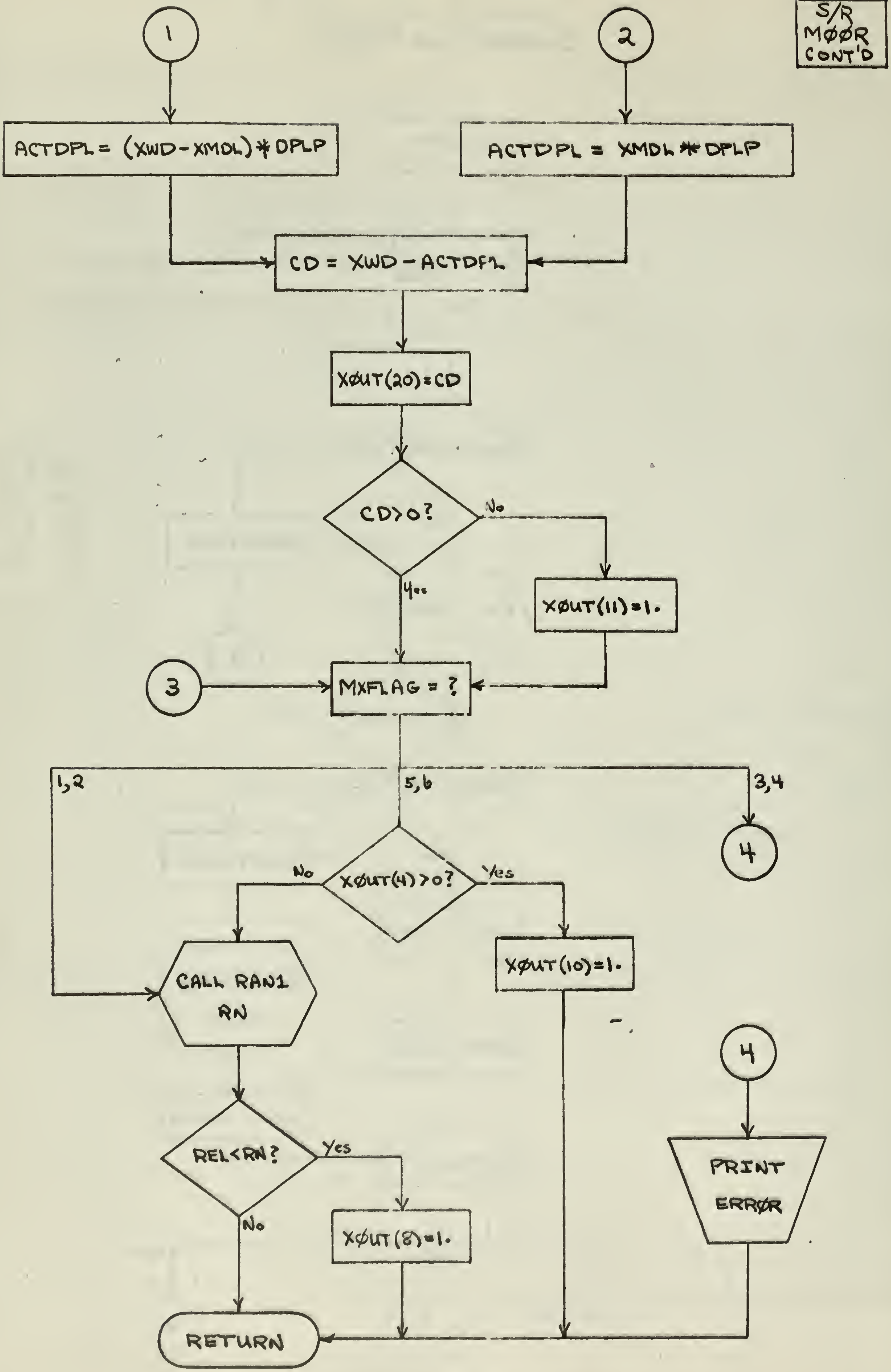


SUBROUTINE BOTTOM

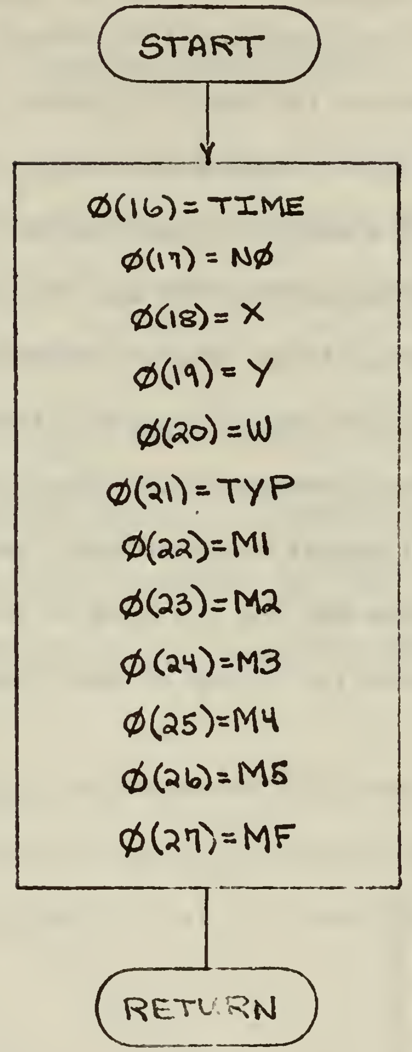


SUBRØUTINE MØÇR




S/R MØØR CONT'D
1
2
ACTDPL = (XWD-XMDL)*DPLP
ACTDPL = XMDL*DPLP
CD = XWD-ACTDPL
XØUT(20)=CD
CD>0?
No
Yes
XØUT(11)=1.
3
MXFLAG = ?
1,2
5,6
3,4
4
XØUT(4)>0?
No
Yes
CALL RAN1 RN
XØUT(10)=1.
4
REL<RN?
Yes
No
XØUT(8)=1.
PRINT ERRØR
RETURN

SUBRØUTINE TAPO



APPENDIX VI

AIRCRAFT CIRCULAR PROBABLE ERROR

The navigational error technique for aircraft used in the mine delivery simulation involves the use of circular probable error (CEP), i.e., the 50 per cent probability circle. The decision to utilize CEP was based on a survey of publications concerning aerial minelaying and the observation that CEP was the most available form of data for aircraft navigational error. The data is generally tabulized with CEP as a function of aircraft altitude for selected ranges of airspeeds. Upon examination of these tables it is clear that CEP does not vary linearly with altitude, and it is here assumed that Altitude versus CEP has the form of the upper right half of a hyperbolic curve with its vertex at the origin as shown in the figure below:

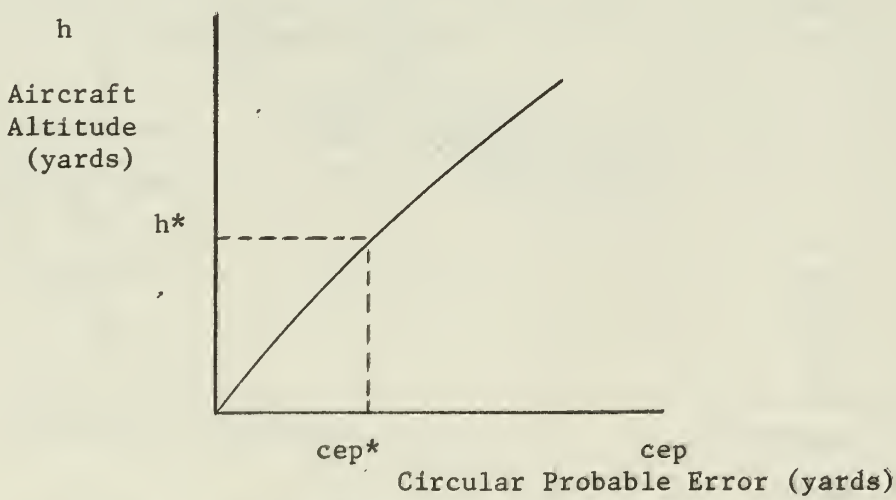


Figure 19. Aircraft Altitude versus Circular Probable Error.

The equation of the curve is:

$$h^2 = (1 - e^2)(1 - (cep - 1)^2)$$

where h = aircraft altitude, e = geometric eccentricity, and cep = radius of Circular Probable Error.

Since the hyperbola passes through the origin, only one other point on the curve is required to determine the hyperbola's eccentricity. Using this fact and re-arranging the foregoing equation, the following formulation results:

$$e^* = ((1 - (cep^* - 1)^2 - h^{*2}) / (1 - (cep^* - 1)^2))^{\frac{1}{2}}$$

where e^* = computed geometric eccentricity, h^* = 1000 yards or 3000 feet of aircraft altitude, and cep^* = CEP for 3000 feet of aircraft altitude from the Aircraft Mine Characteristics List in yards.

Again re-arranging the equation and using the calculated eccentricity, e^*, and the aircraft's minelaying altitude, H, from the Aircraft Characteristics List, the particular CEP is calculated:

$$CEP = (1 - (H^2 / (1 - e^{*2})))^{\frac{1}{2}} + 1$$

Utilizing this calculated CEP and the definition of CEP, the deviation of a normal distribution is determined:

$$Sigma = (CEP / 1.1774)$$

Assuming the normal distribution has mean zero, i.e., centered at the mine's intended position, and the above deviation, the X and Y errors are generated by using the approximation[6]:

$$\text{Error} = \frac{\sum_{i=1}^{N} Z_i - N\,(E(Z))}{N^{\frac{1}{2}}\,(\text{dev.}(Z))} \quad (\text{ Sigma })$$

where Z is uniform (0,1).

The X and Y errors are algebraically added to the X and Y coordinates, respectively, of the mine's intended position to determine the final mine position.

[6]E. Parzen, Modern Probability and Its Application (New York: John Wiley and Sons, Inc., 1960), p.431.

APPENDIX VII

NAVIGATIONAL ERROR

A method of accurately simulating the problem of navigational error is required. Basically, a mine is to be layed at a precise geographical position, but the probability that the mine will be layed at exactly that position is zero due to navigational error. It is assumed that this error is Uniform on $(0,2\pi)$ in bearing, but the range distribution must be determined by some other means.

If sufficient data were available for every type of navigational equipment which might be encountered, giving the errors of these equipments under different operating conditions, it is conceivable that acceptable standard deviations for these equipments could be derived. Lacking this data, however,and desiring to provide navigational error information from as simple a routine as possible, the following technique has been adopted to approximate the range distribution. The technique is similar to that used to estimate completion times in a PERT system, but the development of the density function and the transformation of the Uniform (0,1) random variable is taken from the work of Underwood. [16]

The user is required to provide three inputs for each vehicle type navigational error. These three inputs are:

(1) BNE - an optimistic estimate of navigational error

(2) ANE - the <u>most likely</u> navigational error

(3) GNE - a pessimistic estimate of navigational error

As an example, take the case of a surface ship's navigational error. After considering all possible factors which could influence navigational accuracy for the ship type in the minelaying problem, the user may decide to input the following data -

BNE = 50 yds, ANE = 125 yds, GNE = 400 yds

The three estimates of navigational error define a triangular probability density function as shown below:

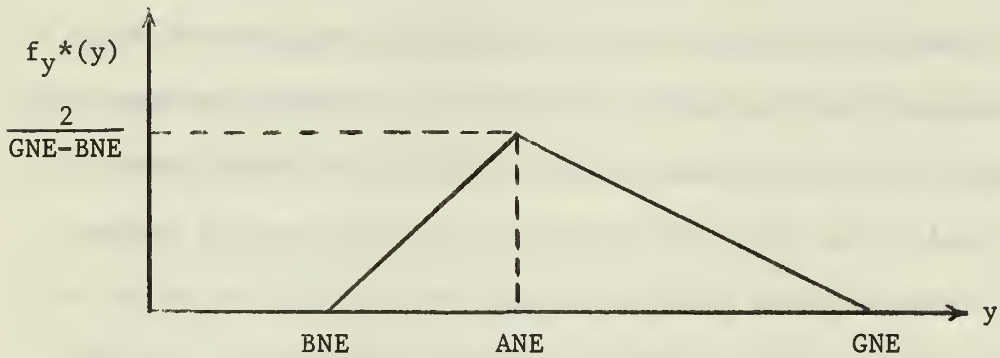


Figure 20. Triangular Density Function

Since the Distribution function of this density may be calculated by a simple formula, the transformation from a sample, u, drawn from a Uniform (0,1) distribution, to a sample from the desired triangular density, may be accomplished by a simple calculation.

The technique is illustrated here for the random variable, y^*, having the general triangular distribution with lower limit BNE, upper limit GNE, and mode ANE.

The density function of y^* is:

$$
\begin{aligned}
f_{y^*}(y) &= \frac{2(y-BNE)}{(GNE-BNE)(GNE-ANE)}, && BNE \le y \le ANE \\
&= \frac{2(GNE-y)}{(GNE-BNE)(GNE-ANE)}, && ANE \le y \le GNE \\
&= 0, && \text{otherwise}
\end{aligned}
$$

The distribution function of y^* is:

$$F_{y^*}(y) = \int_{-\infty}^{y} f_{y^*}(z)\,dz$$

$$= \frac{(y-BNE)^2}{(GNE-BNE)(ANE-BNE)}, \qquad BNE \le y \le ANE$$

$$= \frac{ANE-BNE}{GNE-BNE} + \frac{ANE^2 - 2(GNE)(ANE)+2(GNE)y-y^2}{(GNE-BNE)(GNE-ANE)},$$

$$ANE \le y \le GNE$$

$$= 0, \quad y \le BNE$$

$$= 1, \quad y \ge GNE$$

Now, let $u = F_{y^*}(y)$, and solve for the inverse function,

$y = F_{y^*}^{-1}(u)$, and get

$$y = BNE + \sqrt{u(GNE-BNE)(ANE-BNE)}, \qquad 0 \le u \le \frac{ANE-BNE}{GNE-BNE}$$

$$= GNE - \sqrt{(GNE-ANE)(GNE-BNE)(1-u)}, \qquad \frac{ANE-BNE}{GNE-BNE} \le u \le 1$$

Therefore, if we draw a random number, u, from the Uniform (0,1) distribution, and determine y by means of the above function, then y^* has the desired triangular distribution.

Using the above technique, the procedure for determining the final position of a mine is:

1. Locate the intended position (X,Y Co-ordinates).
2. Generate a random bearing.
3. Generate a random range.
4. Locate the final mine position on the random bearing at the random range from the intended position and convert to X, Y Co-ordinates.

Although there are undoubtedly more accurate methods of simulating navigational error, this method uses very little computer time and it is believed to be accurate enough for the purposes of this model. Additionally, the use of the three error estimates has the advantage of effectively eliminating any bias the user may introduce if only one estimate of navigational error were used.

APPENDIX VIII

SHIP ATTRITION

The determination of ship damage is based on the following assumptions:

1. The longer a ship is in the minelaying objective area the greater its probability of suffering some damage.

2. That this probability of a ship suffering some damage increases exponentially with time in the minelaying objective area.

3. That "damage" can be treated as the cumulative effect of all hits suffered by a ship.

4. The operational commander can give an estimate of the probability of some damage per ship type for the first half-hour period in the minelaying objective area, based on the expected defensive capability of the enemy.

The Probability of a Ship Suffering Some Damage as a function of time is defined as follows:

$$P(t) = e^{(1.4\alpha t)} - 1$$

This function is shown below for several values of alpha.

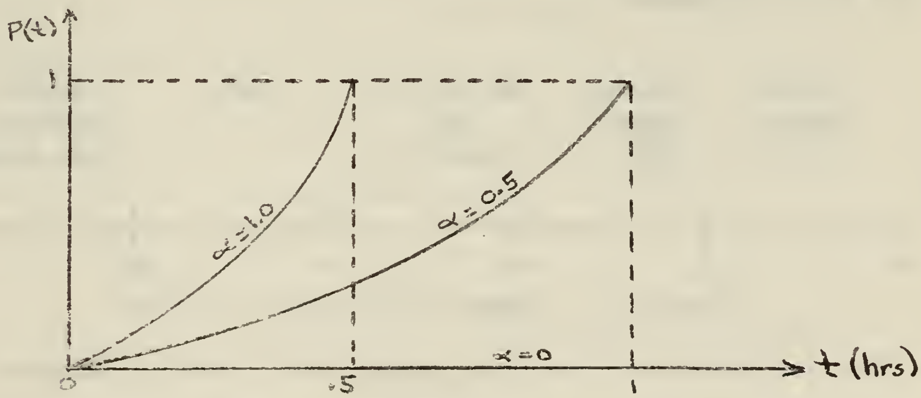


Figure 21. Ship Probability of Damage Function

The procedure for evaluating damage is as follows:

1. User supplies P_u = P(some damage/ship type - first half-hour)

2. Compute

$$\alpha = \frac{\ln(P_u + 1)}{.7}$$

3. Compute time for P(t) = 1 and α as in (2) where

$$P(t) = e^{(1.4\alpha t)} - 1 \quad \text{for all } t,$$

$$T = \frac{1}{2}\left[\frac{\ln 2}{\ln(P_u + 1)}\right]$$

4. Compute total time ship under fire, T_t.

5. Compare T and T_t

(a) If $T_t < T$, $P(t) = e^{(1.4\alpha t)} - 1$

(b) If $T_t \geq T$, $P(t) = 1$

6. If $T_t < T$, compare a U(0,1) random number to $P(T_t)$ to determine if some damage is suffered. If $T_t \geq T$, some damage is suffered.

7. Compare a U(0,1) random number with (0, T_t) to determine the time of damage if the ship suffers some damage.

If the ship is damaged, at the time of damage a uniform random number is compared to the following cumulative damage scale to determine the type of damage.

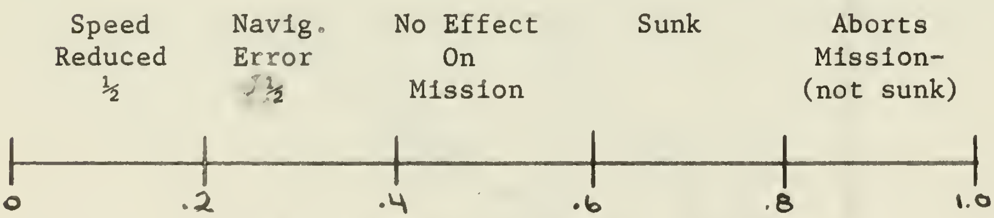


Figure 22. Damage Type Scale for Ships

Note: The increments on the above damage scale can be adjusted, as desired by the user, through a program change.

As an example, suppose the user provides $P_u = 0.2$ as the probability that a ship type will suffer some damage during its first half-hour in the minelaying objective area. Then,

$\alpha = 0.26$

$T = 1.91$ hours

Therefore, if the ship stays in the minelaying objective area for a period of time which is greater than or equal to 1.91 hours, its probability of damage is 1.0. Whereas, if the ship stays less than 1.91 hours its probability of suffering some damage is less than 1. If the ship stays for 1.5 hours,

$P(T_t) = 0.72$

APPENDIX IX

SUBMARINE DETECTION/ATTRITION ROUTINE

Because of the stealth and covertness unique to submarine mining operations, special handling of submarine detection and attrition was adopted. An examination of submarine and enemy capabilities led to the requirement that the user of the mine delivery simulation provide the following eight probabilities which represent the essence of the enemy action and submarine tactics possible:

1. Probability of detection - the chance that the enemy will detect the submarine while it is in the minefield objective area.
2. Probability of knowledge of detection given detection - the chance that the submarine will know he has been detected when actually detected.
3. Probability of thinking detected given no detection - the chance that the submarine considers itself detected when in fact detection has not occurred, e.g., a patrol craft enters the vicinity or an aircraft passes low overhead.
4. Probability of suspending operations given knowledge of detection - the chance or operational doctrine requiring that the submarine suspend operations if it is detected. Suspension of operations always takes place prior to attack or localization.
5. Probability of attempting return to the mining mission given operations have been suspended - the chance or

operational requirement that the submarine return to complete the mission, if it suspends operations.

6. Probability of attack given detection - the chance that the enemy will, and has the means to, press home an attack.
7. Probability of a successful attack given an attack - the chance that the enemy's attack will be a success, i.e., the submarine is sunk.
8. Probability of attempting return given an unsuccessful attack - the chance or operational requirement that the submarine return after surviving attack and evading.

By those probabilities where operational doctrine was indicated, the user is able by inputing zero or one to prescribe the mining mission doctrine for submarines.

Assuming that the marginals of the conditional probabilities and the probability of detection listed in the first paragraph are independent, and hence multiplicative in their intersections, the eight probabilities are combined to form 14 exhaustive and mutually exclusive events which are:

1. The submarine is not detected and does not think it is detected.
2. The submarine is not detected, thinks it is detected, and does not suspend operations.
3. The submarine is not detected, thinks it is detected, suspends operations, and does not attempt return.
4. Same as 3., but the submarine does attempt return.

5. The submarine is detected, knows it is detected, does not suspend operations, and is not attacked.
6. Same as 5., but the submarine is attacked, survives the attack, and does not return.
7. The submarine is detected, knows it is detected, does not suspend operations, is attacked, survives attack, and attempts return.
8. The submarine is detected, does not suspend operations, is attacked, and is sunk.
9. The submarine is detected, knows it is detected, suspends operations, and does not attempt return.
10. Same as 9., but the submarine attempts return.
11. The submarine is detected, does not know it is detected, and is not attacked.
12. The submarine is detected, does not know it is detected, is attacked, and is sunk.
13. The submarine is detected, does not know it is detected, is attacked, survives attack, and does not attempt return.
14. Same as 13., but the submarine does attempt return.

These 14 probabilities are considered distributed with segment lengths proportional to their computed values on the unit interval. A uniform (0,1) random number is compared to this interval to determine which detection and tactical action chain takes place.

In the instances where the submarine suspends operations and attempts return or is attacked and attempts return, the time out of the field is computed by one of two formulations based on the following assumptions:

1. The submarine will transit to beyond the 100 fathom curve in any evasive action.
2. If attacked, the submarine will spend more time in evasion than if he were only detected but not localized.

The time out of the field is computed in terms of the relative time of return (TRET) which for a submarine that has suspended operations is

$$TRET = DT + 2.\ (\ TD100\ ) + (\ TDIF - DT\ )(RN)$$

and for a submarine that has been attacked is

$$TRET = DT + 2.\ (\ TD100\ ) + 2.\ (\ TDIF - DT\ )(RN)$$

where DT is "dead time" in minutes, TD100 is the time it takes to transit to the 100 fathom curve, TDIF is the time of end of mission for submarines relative the submarine's time of arrival in minutes, and RN is a uniform (0,1) random number. The time out of the field for a submarine which has been attacked is greater than that for a submarine which has suspended operations by a factor of (TDIF - DT)(RN).

The submarine returns at computed time and resumes its mining mission provided that the time of return does not exceed the End of Mission Time (TAM) set for submarines and that the mission was not already completed. The submarine upon its return is again subject to detection or attrition based on the same 14 probabilities and a new "dead time" computed from the time remaining to complete the mission. It is conceivable that the submarine may leave and return several times in one operation.

APPENDIX X

SELF-PROPELLED MINE FAILURES

In the Submarine Sequence of Events following the firing of a mine and the determination of the submarine's firing position, it must be determined if the mine is self-propelled. This is accomplished by testing the probability of failure for a self-propelled mine (PF) from the Submarine Mine Characteristics List for the mine type being layed. The value of PF should be zero for mine types that are not self-propelled. Having thus determined that the mine is self-propelled, a uniform random number is compared to PF to determine if a propulsion or control failure occurs. If a failure does not occur, then a circular probable error (CEP) about the mine's intended position is used to determine its final position.

If a failure does occur, the type of failure that takes place must be determined so that the failure characteristics may be considered in calculating the mine's final position. There are three possible types of failure, motor failure, steering failure, and depth control failure. These three failure types are represented by the three probabilities, probability of motor failure, probability of gyro failure, and the probability of depth control failure from the Submarine Mine Characteristics List, and are mutually exclusive and exhaustive. The three probabilities are considered distributed with segment lengths proportional to their values on the unit interval. A uniform random number is compared to this interval to determine which type of failure takes place.

For a motor failure the underlying concept is that the mine will come to rest at a random point along its intended path. This point is calculated by multiplying the directed distance from the submarine's firing position to the mine's intended position by a uniform random number and vectorially adding the resultant value to the submarine's firing position.

For a gyro or steering failure the underlying concept is that the mine will go erratic in steering control at a random point along its intended path, but its motor will continue to run. The mine then will come to rest at a random point in a circle centered at the point the mine went erratic and with a radius equal to length of the remaining intended path. The point at which the mine goes erratic is determined in the same manner as the final resting point for motor failure. To this point a distance calculated by multiplying a uniform random number by the length of the remaining intended path, and directed by 2π times a uniform random number, is vectorially added to determine the mine's final position.

For a depth control failure the concept is that the mine will go erratic in depth control at a random point along its intended path, and thereafter it will hunt about its set running depth in the vertical plane resulting in a reduced distance of advance along its intended path. Again, the point at which the mine goes erratic is determined in the same manner as the final resting point for motor failure. To this point is vectorially added the directed distance of the remaining intended path multiplied by a uniform random number thus determining the mine's final position.

Having determined the mine's final position the sequence for determining the mine parameters is continued in a fashion identical to that for all other mines with one exception. In the case of motor failure the mine must run for a minimum distance, 500 yards as presently programmed, or it will not arm. This minimum arming distance may be changed by modification of the IF statement immediately prior to statement No. 575 of Program MINDEL.

APPENDIX XI

PROGRAM MINDEL1

Program MINDEL1 is an auxiliary program which has as its purpose the printing of the details regarding each mine layed and the compiling of selected statistics to summarize the results of several iterations. In addition to its primary purpose MINDEL1 prints the input to the main program, MINDEL.

At the outset of this program the increment size and the number of increments on both the X and Y axes are established by subroutine DELXY. The increment information is utilized in a later portion of the program to develop distributions of mine positions on the X and Y axes. Following the call of subroutine DELXY, all the input on magnetic tape from the main program is read and printed out in a tabular form with full captioning for easy reference. A sample is shown in Appendix XIII.

That which follows in program MINDEL1 hinges largely upon the structure of a 30-element array called OUTPUT. The elements of OUTPUT are:

1. Chute deployment indicator.
2. Water impact damage indicator.
3. Bottom impact damage indicator.
4. Case/anchor separation indicator.
5. Mooring cable deployment indicator.
6. Buried mine indicator.
7. Did not bury indicator.
8. Reliability indicator.

9. On the beach indicator.

10. Arming failure due to case/anchor separation failure indicator.

11. Mine watching indicator.

12. Arming failure due to short run indicator.

13. Motor failure indicator.

14. Gyro failure indicator.

15. Depth control failure indicator.

16. Time of lay.

17. Mine number.

18. X coordinate of mine's position.

19. Y coordinate of mine's position.

20. Case depth.

21. Mine type II.

22. NWL type.

23. Type of moor.

24. Ship counts.

25. Arming delay.

26. Sterile time.

27. MFLAG.

28. IR.

29. IREP.

30. Time of activation.

In the main program when an event was recorded, it was accomplished by setting the applicable indicator of the 15 indicator elements to zero or one. After determining the outcome of all the events in a particular mine's sequence, OUTPUT was written on magnetic tape.

The OUTPUT arrays are then read singly from tape by MINDEL1 and decoded until an end of file is encountered.

As each OUTPUT is read from magnetic tape, it is determined whether it is the beginning of an iteration or not. If so, all the elements are zero except the run number (IREP) and the random number generator initializing value (IR) which are then printed out. If not, those indicators of the first 15 elements which indicate the mine is inoperable, i.e., unreliable or damaged, are examined. If the mine is fully operable, the time of activation is computed by adding the arming delay to the time of lay and this time is stored in element number 30; otherwise, that element is zero. The full set of the first 15 elements is examined and indices to control the printing of adverse events, if any, are then set. Prior to any printout of the information regarding a mine, the X and Y coordinates are tested and counts are added to the corresponding increments of the X and Y axes. Also the applicable counts are added to the following statistics:

1. Number of mines layed.
2. Number of mines effective.
3. Number of mines buried.
4. Number of mines not buried.
5. Number of mines compromised.

All mines not damaged, unreliable, on the beach, or which failed to arm are considered effective. The number of mines buried (not buried) is the count of those mines for which burying (not burying) is undesirable. Compromised mines are those mines whose final positions are on the beach or those moored mines which are watching. The mine number, time of lay, time of activation, X and Y coordinates, and case depth along with comment on adverse events are then printed for each mine layed. At the end of each iteration the total of the five statistics listed above is shown. Since the foregoing process generally exceeds the capacity of a standard output tape, subroutine STP was included to write an end file mark on the standard output tape and stop the program for changing the standard output tape at the computer operator's discretion.

Upon completion of processing all the OUTPUTs, a summary table of the five statistics along with the average of all the runs is presented. The count distribution on the X and Y axes is normalized, i.e., converted to a frequency distribution. The frequency distribution is then converted to a cumulative distribution. The values for both the frequency and cumulative distributions on the X and Y axes are then written on magnetic tape for use in program LSQRPLOT.

Sample output from program MINDEL1 appears in Appendix XIII. The program listing follows in this appendix. Preceding the program listing appear two pages describing the data deck for this program. The first of these two pages is of particular importance. It lists 15 cards containing alpha-numeric phrases which _must_ appear in the order shown and as the first 15 cards of the data deck, since they are an integral part of the program's logic. On the succeeding page appears the description of the single additional data card required. As described in Appendices I, II, and

III, the card strip with letters is presented followed by columns of letter keys, FORTRAN specifications, variable names, and brief definitions.

THE FOLLOWING PHRASES,PUNCHED UNDER FORMAT(7A8) MUST APPEAR AS THE FIRST FIFTEEN (15) DATA CARDS.

```
CHUTE DID NOT DEPLOY.
DAMAGED ON WATER IMPACT.
DAMAGED ON BOTTOM IMPACT.
CASE/ANCHOR SEPARATION FAILURE.
MOORING CABLE DID NOT DEPLOY FULLY.
BURIED.
DID NOT BURY.
UNRELIABLE.
ON THE BEACH.
DID NOT ARM DUE TO CASE/ANCHOR SEPARATION FAILURE.
MINE IS WATCHING.
DID NOT ARM DUE TO SHORT RUN.
MOTOR FAILURE.
GYRO FAILURE.
DEPTH FAILURE.
```

PROGRAM MINDEL1

INPUT DATA

1. DATA CARD

```
AAAAA:AAAAAABBBBB:BBBBBBCCCCC:CCCCCCDDDDD:DDDDDD
```

C FOR COMMENT / STATEMENT NUMBER	CONTINUATION	FORTRAN STATEMENT	IDENTIFICATION
0 0 0 0 0	0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0
1 2 3 4 5	6	7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72	73 74 75 76 77 78 79 80

```
A.    F12.6  DELX   INCREMENT ON X-AXIS(YDS).
B.    F12.6  DELY   INCREMENT ON Y-AXIS(YDS).
C.    F12.6  XHALF  MEDIAN LENGTH OF X-AXIS(YDS). SAME AS XMEANX IN
                    PROGRAM SURFIT.
D.    F12.6  YHALF  MEDIAN LENGTH OF Y-AXIS(YDS). SAME AS YMEANY IN
                    PROGRAM SURFIT.
```

```
      PROGRAM MINDEL1
      DIMENSION ACLDL(8,31),SHLDL(7,70),SULDL(4,37),VAL(50,11),ACCL(10,6
     1),SHCL(10,9),SUCL(10,17),ACMCL(24,14),SHMCL(10,8),SUMCL(8,13),BR(7
     2,6),MDL(167,8),OUTPUT(30),PHRASE(105),KK(15),FXPTS(10),FYPTS(10)
     3,X(500),Y(500),XSTAT(500),YSTAT(500),NSTAT(100,5),NTOT(5)
      COMMON ACLDL,SHLDL,SULDL,VAL,ACCL,SHCL,SUCL,ACMCL,SHMCL,SUMCL,MDL,
     1X,Y,XSTAT,YSTAT,NSTAT
      READ 91,(PHRASE(J),J=1,105)
   91 FORMAT(7A8)
      READ 511,DELX,DELY,XHALF,YHALF
  511 FORMAT(4F12.6)
      CALL DELXY(X,Y,XSTAT,YSTAT,DELX,DELY,XHALF,YHALF,NUMX,NUMY,XINC,YI
     1NC)
      READ TAPE 2,XREF,YREF,FXPTS,FYPTS,ACLDL,SHLDL,SULDL,VAL,ACCL,SHCL,
     1SUCL,ACMCL,SHMCL,SUMCL,BR,MDL,NV,NA,NAT,NACR,NACC,MACT,NSH,NSHT,NS
     2HR,NSHC,MSHT,NSU,NSUT,NSUR,NSUC,MSUT,MINTOT,NF,TAM
      PRINT 5
    5 FORMAT(1H1,45X,29H INPUT TO MINE DELIVERY PHASE //)
      PRINT 600
  600 FORMAT(54X,11H FIELD DATA //)
      PRINT 601,XREF,YREF
  601 FORMAT(28H THE X REFERENCE POSITION IS,F10.4,8H DEGREES // 28H THE
     1 Y REFERENCE POSITION IS,F10.4,8H DEGREES //)
      PRINT 602,(FXPTS(I),FYPTS(I),I=1,NF)
  602 FORMAT(48X,23H FIELD PERIMETER POINTS // 50X,19H XCOORD      YCOOR
     1D   // (49X,F10.4,2X,F10.4/))
      PRINT 6
    6 FORMAT(//50X,21H VEHICLE ARRIVAL LIST //)
      PRINT 7
    7 FORMAT(3X,4H TOA,4X,8H VEHICLE,2X,8H VEHICLE,3X,12H TOTAL NO.OF,2X
     1,11H NO.OF BOMB,22X,14H LEGS ASSIGNED /13X,5H TYPE,3X,7H NUMBER,3X
     2,14H LEGS ASSIGNED,3X,6H RACKS,28X,8H (CODED) //)
      PRINT 8,((VAL(I,J),J=1,11),I=1,NV)
    8 FORMAT(F10.1,3X,F4.0,7X,F3.0,8X,F3.0,13X,F3.0,1X,F10.0,1X,F10.0,1X
     1,F10.0,1X,F10.0,1X,F10.0,1X,F10.0)
```

```
      PRINT 11
   11 FORMAT(////46X,30H AIRCRAFT CHARACTERISTICS LIST  //)
      PRINT 12
   12 FORMAT(3X,13H VEHICLE TYPE,4X,11H XSIT SPEED,4X,10H M/L SPEED,4X,1
     13H M/L ALTITUDE,4X,21H PROB OF MINE RELEASE,4X,22H PROB OF SURVIVA
     2L OVER  /94X,15H OBJECTIVE AREA  //)
      PRINT 13,((ACCL(I,J),J=1,6),I=1,NAT)
   13 FORMAT(8X,F5.0,10X,F5.0,10X,F5.0,11X,F5.0,16X,F4.2,20X,F4.2)
      PRINT 14
   14 FORMAT(1H1,45X,30H AIRCRAFT LEG DESCRIPTION LIST //)
      PRINT 15
   15 FORMAT(41H LEG  NO.OF MINES  AIRCRAFT INITIAL POSIT,6X,9H MINE NO.
     1,8X,23H MINE INTENDED POSITION,3X,24H AIRCRAFT TERMINAL POINT/4H N
     2O.,2X,10H THIS  LEG,4X,18H XCOORD      YCOORD,28X,19H XCOORD       Y
     3COORD,7X,20H XCOORD        YCOORD  //)
      DO100 I=1,NACR
      PRINT 16,(ACLDL(I,J),J=1,4)
   16 FORMAT(F5.0,5X,F4.0,5X,F10.3,2X,F10.3)
      NSTOP = 3*XINTF(ACLDL(I,2)) + 4
      PRINT 17,(ACLDL(I,K),K=5,NSTOP)
   17 FORMAT(42X,F10.0,13X,F10.3,2X,F10.3/)
      NSTOP1 = NSTOP + 2
      NSTOP2 = NSTOP + 3
      PRINT 18,(ACLDL(I,J),J=NSTOP1,NSTOP2)
   18 FORMAT(91X,F10.3,3X,F10.3//)
  100 CONTINUE
      PRINT 19
   19 FORMAT(1H1,46X,16H BOMB RACK ARRAY //)
      PRINT 20
   20 FORMAT(22H A/C BOMB RACK NO. ONE,13X,4H TWO,14X,6H THREE,14X,5H FO
     1UR,14X,5H FIVE,14X,4H SIX/4H NO. //)
      DO101 I=1,NA
      PRINT 21,I,(BR(I,J),J=1,6)
   21 FORMAT(I4,F19.0,F19.0,F19.0,F19.0,F19.0,F19.0)
  101 CONTINUE
```

```
      PRINT 22
   22 FORMAT(1H1,42X,35H AIRCRAFT MINE CHARACTERISTICS LIST //)
      PRINT 23
   23 FORMAT(11H MINE TYPE ,3X,3H A ,3X,5H  B  ,3X,5H  C  ,3X,3H D ,3X,3
     1H E ,3X,3H F ,3X,3H G ,3X,3H H ,3X,2H I,3X,2H J,3X,3H K ,3X,3H L
     2,3X,3H M ,/3X,5H (II))
      PRINT 24,((ACMCL(I,J),J=1,14),I=1,MACT)
   24 FORMAT(F6.0,7X,F4.2,3X,F5.0,3X,F5.0,3X,F3.2,3X,F3.2,3X,F3.2,3X,F3.
     12,3X,F3.2,3X,F2.0,3X,F2.0,3X,F3.2,3X,F3.2,3X,F3.2)
      PRINT 25
   25 FORMAT(29H A = PROB OF CHUTE DEPLOYMENT / 32H B = CEP FOR 3K FT,CH
     1UTE DEPLOYS / 40H C = CEP FOR 3K FT,CHUTE DOES NOT DEPLOY / 46H D
     2= PROB OF WATER IMPACT DAMAGE,CHUTE DEPLOYS / 54H E = PROB OF WATE
     3R IMPACT DAMAGE,CHUTE DOES NOT DEPLOY / 93H F = PROB OF IMPACT DAM
     4AGE ON THE HARDEST BOTTOM,GIVEN DEPTH LESS THAN 20FT AND CHUTE DEP
     5LOYS / 97H G = PROB OF IMPACT DAMAGE ON HARDEST BOTTOM,GIVEN DEPTH
     6 LESS THAN 20FT AND CHUTE DOES NOT DEPLOY / 38H H = PROB OF BURYIN
     7G IN SOFTEST BOTTOM / 37H I = INDICATOR OF MOOR OR BOTTOM TYPE / 4
     89H J = NWL TYPE IF BOTTOM MINE DOES NOT BURY/BURIES / 35H K = PROB
     9 OF CASE/ANCHOR SEPARATION)
      PRINT 26
   26 FORMAT(41H L = PROB OF FULL ANCHOR CABLE DEPLOYMENT / 68H M = PROB
     1 MINE OPERATES,GIVEN IT HAS NOT BEEN DAMAGED (RELIABILITY)  //)
      PRINT 250
  250 FORMAT(1H1,48X,25H SHIP CHARACTERISTIC LIST //)
      PRINT 251
  251 FORMAT(3X,13H VEHICLE TYPE,4X,11H XSIT SPEED,4X,10H M/L SPEED,5X,1
     19H NAVIGATIONAL ERROR,5X,9H PROB  OF,2X,23H MAX     PROB OF DAMAGE
     2/76X,32H MINE     TIME    FOR FIRST HALF/48X,59H LEAST  AVERAGE  G
     3REATEST  RELEASE   DELAY     HOUR IN MLOA//)
      PRINT 252,((SHCL(I,J),J=1,9),I=1,NSHT)
  252 FORMAT(8X,F5.0,10X,F5.0,10X,F5.0,6X,F5.0,3X,F5.0,4X,F5.0,7X,F3.2,5
     1X,F3.1,10X,F3.2)
      PRINT 267
  267 FORMAT(1H1,46X,26H SHIP LEG DESCRIPTION LIST//)
```

```
      PRINT 268
  268 FORMAT(41H LEG  NO.OF MINES    SHIP INITIAL POSIT  ,6X,9H MINE NO.
     1,8X,23H MINE INTENDED POSITION,3X,24H   SHIP TERMINAL POINT  /4H N
     2O.,2X,10H THIS  LEG,4X,18H XCOORD      YCOORD,28X,19H XCOORD      Y
     3COORD,7X,20H XCOORD       YCOORD  //)
      DO300 I=1,NSHR
      PRINT 269,(SHLDL(I,J),J=1,4)
  269 FORMAT(F5.0,5X,F4.0,5X,F10.3,2X,F10.3)
      MSTOP = 3*XINTF(SHLDL(I,2)) + 4
      PRINT 270,(SHLDL(I,K),K=5,MSTOP)
  270 FORMAT(42X,F10.0,13X,F10.3,2X,F10.3/)
      MSTOP1 = MSTOP + 2
      MSTOP2 = MSTOP + 3
      PRINT 271,(SHLDL(I,J),J=MSTOP1,MSTOP2)
  271 FORMAT(91X,F10.3,3X,F10.3//)
  300 CONTINUE
      PRINT 253
  253 FORMAT(////45X,30H SHIP MINE CHARACTERISTIC LIST//)
      PRINT 254
  254 FORMAT(66H MINE TYPE       A       B       C       D       E
     1 F       G/3X,5H (II) )
      PRINT 255,((SHMCL(I,J),J=1,8),I=1,MSHT)
  255 FORMAT(4X,F3.0,9X,F3.2,5X,F3.2,5X,F3.0,5X,F3.0,5X,F3.2,5X,F3.2,5X,
     1F3.2)
      PRINT 266
  266 FORMAT(/64H A = PROB OF DAMAGE ON HARDEST BOTTOM,GIVEN DEPTH LESS
     1THAN 20FT /38H B = PROB OF BURYING IN SOFTEST BOTTOM /37H C = INDI
     2CATOR OF MOOR OR BOTTOM TYPE /48H D = NWL TYPE IF BOTTOM MINE DOES
     3NOT BURY/BURIES /35H E = PROB OF CASE/ANCHOR SEPARATION /41H F = P
     4ROB OF FULL ANCHOR CABLE DEPLOYMENT /67H G = PROB MINE OPERATES,GI
     5VEN IT HAS NOT BEEN DAMAGED (RELIABILITY) //)
      PRINT 425
  425 FORMAT(1H1,45X,30H SUBMARINE CHARACTERISTIC LIST //)
      PRINT 426
  426 FORMAT(41H VEHICLE  XSIT   M/L    NAVIGATION  ERROR,2X,74H PMR  FT
```

```
   1DM  PD  PKD/D  PKD/ND  PSO/KD  PR/SO  PR/UA  PA/D  PSA/A    D(100)
   2/42H  TYPE   SPEED  SPEED  BEST  AVG  GREATEST )
    PRINT 427,((SUCL(I,J),J=1,17),I=1,NSUT)
427 FORMAT(2X,F2.0,5X,F5.0,2X,F5.0,1X,F5.0,1X,F5.0,2X,F5.0,4X,F3.2,2X,
   1F4.1,2X,F3.2,2X,F3.2,4X,F3.2,5X,F4.1,3X,F4.1,3X,F4.1,3X,F3.2,4X,F3
   2.2,3X,F10.0)
    PRINT 428
428 FORMAT(/43H PMR    = PROB MINE IS READY AT FIRING TIME /37H FTDM
   1 = FIRING TIME DELAY (MAXIMUM) /80H PKD/D  = PROB SUBMARINE HAS KN
   2OWLEDGE OF DETECTION,GIVEN DETECTION HAS OCCURRED /73H PKD/ND = PR
   3OB SUBMARINE THINKS DETECTION HAS OCCURRED,GIVEN NO DETECTION /73H
   4 PSO/KD = PROB SUBMARINE SUSPENDS OPS,GIVEN IT HAS KNOWLEDGE OF DE
   5TECTION /59H PR/SO  = PROB SUBMARINE RETURNS,GIVEN IT HAD SUSPENDE
   6D OPS /57H PR/UA  = PROB SUBMARINE RETURNS,GIVEN UNSUCCESFUL ATTAC
   7K /40H PA/D   = PROB OF ATTACK,GIVEN DETECTION /48H PSA/A  = PROB
   8OF SUCCESSFUL ATTACK,GIVEN ATTACK /63H D(100) = DISTANCE FROM MINE
   9FIELD PERIMETER TO 100 FATHOM CURVE //)
    PRINT 434,TAM
434 FORMAT(//52H DATE-TIME FOR COMPLETION OF SUBMARINE OPERATIONS IS,F
   110.1 /)
    PRINT 320
320 FORMAT(1H1,44X,31H SUBMARINE LEG DESCRIPTION LIST //)
    PRINT 321
321 FORMAT(38H LEG  NO.OF MINES    SUB INITIAL POSIT,3X,73H MINE   SUB
   1 FIRING POSIT    MINE INTENDED POSITION     SUB TERMINAL POINT/38H
   2 NO.   THIS  LEG     XCOORD      YCOORD,4X,72H NO.   XCOORD    YCOO
   3RD     XCOORD      YCOORD       YCOORD      YCOORD //)
    DO400 I=1,NSUR
    PRINT 269,(SULDL(I,J),J=1,4)
    KSTOP = 5*XINTF(SULDL(I,2)) + 4
    PRINT 410,(SULDL(I,K),K=5,KSTOP)
410 FORMAT(42X,F4.0,1X,F10.3,1X,F10.3,2X,F10.3,2X,F10.3/)
    KSTOP1 = KSTOP + 2
    KSTOP2 = KSTOP + 3
    PRINT 420, (SULDL(I,J),J=KSTOP1,KSTOP2)
```

```
420 FORMAT(95X,F10.3,1X,F10.3)
400 CONTINUE
    PRINT 430
430 FORMAT(1H1,42X,35H SUBMARINE MINE CHARACTERISTIC LIST //)
    PRINT 431
431 FORMAT(10H MINE TYPE,5X,68H A      B      C      D      E      F      G
   1    H      I      J      K      L /2X,5H (II) )
    PRINT 432,((SUMCL(I,J),J=1,13),I=1,MSUT)
432 FORMAT(2X,F5.0,8X,F3.2,3X,F3.2,3X,F3.0,2X,F5.0,2X,F3.2,3X,F3.2,3X,
   1F3.2,3X,F3.2,3X,F3.2,3X,F3.2,2X,F5.0,2X,F3.2 )
    PRINT 433
433 FORMAT(/37H A = PROB OF DAMAGE ON HARDEST BOTTOM /38H B = PROB OF
   1BURYING IN SOFTEST BOTTOM /37H C = INDICATOR OF MOOR OR BOTTOM TYP
   2E /49H D = NWL TYPE IF BOTTOM MINE DOES NOT BURY/BURIES /35H E = P
   3ROB OF CASE/ANCHOR SEPARATION /41H F = PROB OF FULL ANCHOR CABLE D
   4EPLOYMENT /49H G = PROB OF NORMAL RUN FOR A SELF-PROPELLED MINE /4
   50H H = PROB OF MOTOR FAILURE,GIVEN FAILURE /39H I = PROB OF GYRO F
   6AILURE,GIVEN FAILURE /40H J = PROB OF DEPTH FAILURE,GIVEN FAILURE
   7/46H K = CEP FOR NORMAL RUN OF SELF-PROPELLED MINE /67H L = PROB M
   8INE OPERATES,GIVEN IT HAS NOT BEEN DAMAGED (RELIABILITY) //)
    PRINT 66
 66 FORMAT(1H1,45X,22H MINE DESCRIPTION LIST //)
    PRINT 67
 67 FORMAT(2X,5H MINE,5X,5H MINE,6X,5H MINE,6X,5H MINE,6X,7H ARMING,4X
   1,8H STERILE,4X,5H SHIP,4X,8H TYPE OF /9H CASE NO.,2X,8H TYPE II,3X
   2,7H TYPE I,2X,11H CASE DEPTH,4X,6H DELAY,5X,5H TIME,5X,7H COUNTS,4
   3X,5H MOOR//)
    PRINT 68,((MDL(I,J),J=1,8),I=1,MINTOT)
 68 FORMAT(2X,I5,6X,I5,5X,I5,7X,I5,5X,I8,5X,I5,6X,I5,5X,I5)
    DO 512 I=1,100
    DO 513 J = 1,5
513 NSTAT(I,J) = 0
512 CONTINUE
200 CALL STP
    READ TAPE 2,OUTPUT
```

```
      IF(EOF,2)9999,202
  202 IF((OUTPUT(2).EQ.0.).AND.(OUTPUT(3).EQ.0.).AND.(OUTPUT(8).EQ.0.).A
     1ND.(OUTPUT(9).EQ.0.).AND.(OUTPUT(10).EQ.0.).AND.(OUTPUT(12).EQ.0.)
     2)1000,201
 1000 JOUT = XINTF(OUTPUT(17))
      ARMDEL = FLOATF(MDL(JOUT,5))
      CALL TIMCON(OUTPUT(16),ARMDEL,OUTPUT(30))
  201 JJ = 0
      DO 500 II=1,15
  500 KK(II) = 0
      DO 30 I=1,15
      IF(OUTPUT(I))220,30,220
  220 JJ = JJ + 1
      KK(JJ) = (I-1)*7 + 1
   30 CONTINUE
      IF(JJ)31,32,31
   32 IF(OUTPUT(28))34,33,34
   34 IR = XINTF(OUTPUT(28))
      IREP = XINTF(OUTPUT(29))
      IF(IREP.EQ.1)9998,9997
 9997 MMM = IREP - 1
      PRINT 9996,(NSTAT(MMM,J),J=1,5)
 9996 FORMAT(////13H  MINES LAYED,I5,17H  MINES EFFECTIVE,I4,14H  MINES
     1BURIED,I4,18H  MINES NOT BURIED,I4,19H  MINES COMPROMISED,I4 /)
 9998 PRINT 35,IREP,IR
   35 FORMAT(1H1,8H RUN NO.,I3,23H   IR FOR THIS RUN IS  ,I8 //)
      PRINT 106
  106 FORMAT(51X,19H DETAILED NARRATIVE ///79H MINE NO.  TIME     TIME
     1   XCOORD    YCOORD    CASE                       REMARKS/54H
     2 LAYED    ACTIVE                            DEPTH /29X,25H (YDS)     (
     3YDS)     (FT) //)
      GO TO 200
   33 PRINT 105,OUTPUT(17),OUTPUT(16),OUTPUT(30),(OUTPUT(J),J=18,20)
      CALL COUNT(XSTAT,YSTAT,DELX,DELY,OUTPUT(18),OUTPUT(19),XHALF,YHALF
     1)
```

```
      CALL COMPIL(OUTPUT,NSTAT,IREP)
      GO TO 200
   31 DO 40 J=1,15
      IF(KK(J))42,41,42
   42 GO TO(114,115,116,117,118,119,120,121,122,123,124,140,141,142,143)
     1,J
  114 K1 = KK(1)
      K11 = K1 + 6
      GO TO 40
  115 K2=KK(2)
      K22=K2+6
      GO TO 40
  116 K3=KK(3)
      K33=K3+6
      GO TO 40
  117 K4=KK(4)
      K44=K4+6
      GO TO 40
  118 K5=KK(5)
      K55=K5+6
      GO TO 40
  119 K6=KK(6)
      K66=K6+6
      GO TO 40
  120 K7=KK(7)
      K77=K7+6
      GO TO 40
  121 K8=KK(8)
      K88 = K8+6
      GO TO 40
  122 K9=KK(9)
      K99=K9+6
      GO TO 40
  123 K10=KK(10)
      K100=K10+6
```

```
      GO TO 40
  124 K111=KK(11)
      K1110=K111+6
      GO TO 40
  140 K112=KK(12)
      K1120=K112+6
      GO TO 40
  141 K113=KK(13)
      K1130=K113 + 6
      GO TO 40
  142 K114=KK(14)
      K1140=K114+6
      GO TO 40
  143 K115=KK(15)
      K1150=K115+6
      GO TO 40
   41 GO TO(125,126,127,128,129,130,131,132,133,134,135,144,145,146,147)
     1,J
  125 K11=-10
      K1 = 0
      GO TO 40
  126 K22=-10
      K2 = 0
      GO TO 40
  127 K33=-10
      K3 = 0
      GO TO 40
  128 K44=-10
      K4 = 0
      GO TO 40
  129 K55=-10
      K5 = 0
      GO TO 40
  130 K66=-10
      K6 = 0
```

```
      GO TO 40                                                          02740
  131 K77=-10                                                           02750
      K7 = 0                                                            02755
      GO TO 40                                                          02760
  132 K88=-10                                                           02770
      K8 = 0                                                            02775
      GO TO 40                                                          02780
  133 K99=-10                                                           02790
      K9 = 0                                                            02795
      GO TO 40                                                          02800
  134 K100 = -10                                                        02810
      K10 = 0                                                           02815
      GO TO 40                                                          02820
  135 K1110=-10                                                         02830
      K111 = 0                                                          02835
      GO TO 40                                                          02840
  144 K1120=-10                                                         02850
      K112 = 0                                                          02855
      GO TO 40                                                          02860
  145 K1130=-10                                                         02870
      K113 = 0                                                          02875
      GO TO 40                                                          02880
  146 K1140=-10                                                         02890
      K114 = 0                                                          02895
      GO TO 40                                                          02900
  147 K1150=-10                                                         02910
      K115 = 0                                                          02915
   40 CONTINUE                                                          02920
      PRINT 105,OUTPUT(17),OUTPUT(16),OUTPUT(30),(OUTPUT(J),J=18,20),(PH 02930
     1RASE(I),I=K1,K11),(PHRASE(I),I=K2,K22),(PHRASE(I),I=K3,K33),(PHRAS 02940
     2E(I),I=K4,K44),(PHRASE(I),I=K5,K55),(PHRASE(I),I=K6,K66),(PHRASE(I 02950
     3),I=K7,K77),(PHRASE(I),I=K8,K88),(PHRASE(I),I=K9,K99),(PHRASE(I),I 02960
     4=K10,K100),(PHRASE(I),I=K111,K1110),(PHRASE(I),I=K112,K1120),(PHRA 02970
     5SE(I),I=K113,K1130),(PHRASE(I),I=K114,K1140),(PHRASE(I),I=K115,K11 02980
     650)                                                               02985
```

```
 105 FORMAT(//2X,F4.0,2F10.1,2F10.3,1X,F7.2,4X,7A8,(/58X,7A8))
     CALL COUNT(XSTAT,YSTAT,DELX,DELY,OUTPUT(18),OUTPUT(19),XHALF,YHALF
    1)
     CALL COMPIL(OUTPUT,NSTAT,IREP)
     GO TO 200
9999 PRINT 9996,(NSTAT(IREP,J),J=1,5)
     PRINT 520
 520 FORMAT(1H1,50X,18HSUMMARY OF RESULTS //8X,61HRUN NO.      MINES LA
    1YED     MINES EFFECTIVE     MINES BURIED ,43H     MINES NOT BURIED
    2     MINES COMPROMISED //)
     PRINT 505,(I,(NSTAT(I,J),J=1,5),I=1,IREP)
 505 FORMAT(8X,I5,10X,I4,14X,I4,15X,I4,17X,I4,16X,I4)
     CALL AGGREG(NSTAT,IREP,NTOT)
     PRINT 510,(NTOT(J),J=1,5)
 510 FORMAT(/8X,7HAVERAGE,9X,I4,14X,I4,15X,I4,17X,I4,16X,I4 /)
     WRITE TAPE 3,NUMX,NUMY,X,Y,FXPTS,FYPTS,NF,XHALF,YHALF,NTOT(1)
9995 CALL NRMLZ(XSTAT,YSTAT,NUMX,NUMY)
     WRITE TAPE 3,XSTAT,YSTAT
     CALL CMLTV ( XSTAT,YSTAT,NUMX,NUMY)
     WRITE TAPE 3,XSTAT,YSTAT
     END
```

```
SUBROUTINE TIMCON (ARTDHM,TD,TF)
ND=ARTDHM/ 10000.0
AND = ND
ARTHM = ARTDHM - AND * 10000.0
NH = ARTHM/100.0
ANH = NH
ARTM = ARTHM - ANH * 100.0
 TEMT = ARTM + TD
NTEH = TEMT / 60.0
ANTEH = NTEH
TEM = TEMT - ANTEH * 60.0
NTED =(ANTEH +ANH)/24.0
ANTED=NTED
TEH=ANTEH + ANH - ANTED*24.0
TE = TEM + TEH * 100.0 + (ANTED + AND) * 10000.0
RETURN
END
```

```
      SUBROUTINE DELXY(X,Y,XSTAT,YSTAT,DELX,DELY,XHALF,YHALF,NUMX,NUMY,X
     1INC,YINC)
      DIMENSION X(500),Y(500),XSTAT(500),YSTAT(500)
      XDIV = (2.*XHALF)/DELX  $  YDIV = (2.*YHALF)/DELY
      NUMX = XFIXF(XDIV)+ 1   $   NUMY = XFIXF(YDIV) + 1
      X(1) = 0.  $  Y(1) = 0.  $  XSTAT(1) = 0.  $  YSTAT(1) = 0.
      XINC = (2.*XHALF)/FLOATF(NUMX)  $  YINC = (2.*YHALF)/FLOATF(NUMY)
      DO 1 I = 2,NUMX
      X(I) = X(I-1) + XINC
    1 XSTAT(I) = 0.
      DO 2 I = 2,NUMY
      Y(I) = Y(I-1) + YINC
    2 YSTAT(I) = 0.
      RETURN
      END
```

```
      SUBROUTINE COUNT( XSTAT,YSTAT,DELX,DELY,XPOSIT,YPOSIT,XHALF,YHALF
     1)
      DIMENSION XSTAT(500),YSTAT(500)
      IF((XPOSIT.LT.0.).OR.(YPOSIT.LT.0.).OR.(XPOSIT.GT.(2.*XHALF)).OR.(
     1YPOSIT.GT.(2.*YHALF)))5,6
    6 TX = XPOSIT / DELX
      TY = YPOSIT / DELY
      JX = XFIXF(TX)  $  XJ = FLOATF(JX)
      JY = XFIXF(TY)  $  YJ = FLOATF(JY)
      IF(DIMF(TX,XJ).GT..5)1,2
    1 JX = JX + 1
    2 IF(DIMF(TY,YJ).GT..5)3,4
    3 JY = JY + 1
    4 XSTAT(JX) = XSTAT(JX) + 1.0
      YSTAT(JY) = YSTAT(JY) + 1.0
    5 RETURN
      END
```

```
      SUBROUTINE  NRMLZ( XSTAT,YSTAT,NUMX,NUMY)
      DIMENSION XSTAT(500),YSTAT(500)
      XTOT = 0.
      DO 1 I=1,NUMX
    1 XTOT = XTOT + XSTAT(I)
C     PRINT 20,XTOT
C  20 FORMAT(1H0,E15.8/)
      DO 2 I=1,NUMX
    2 XSTAT(I) = XSTAT(I) / XTOT
      DO 3 I = 1,NUMY
    3 YSTAT(I) = YSTAT(I) / XTOT
C     PRINT 10,(X(I),XSTAT(I),I=1,NUMX)
C     PRINT 10,(Y(I),YSTAT(I),I=1,NUMY)
C  10 FORMAT(1H1,(E15.8,10X,E15.8))
      RETURN
      END
```

```
      SUBROUTINE COMPIL(OUTPUT,NSTAT,IREP)
      DIMENSION OUTPUT(30),NSTAT(100,5)
      NSTAT(IREP,1) = NSTAT(IREP,1) + 1
      SUMO = OUTPUT(2) + OUTPUT(3) + OUTPUT(8) + OUTPUT(9) + OUTPUT(10)
     1 + OUTPUT(11) +OUTPUT(12)
      IF(SUMO)1,1,2
    1 NSTAT(IREP,2) = NSTAT(IREP,2) + 1
    2 IF(OUTPUT(6))4,4,3
    3 NSTAT(IREP,3) = NSTAT(IREP,3) + 1
    4 IF(OUTPUT(7))6,6,5
    5 NSTAT(IREP,4) = NSTAT(IREP,4) + 1
    6 IF(OUTPUT(9))8,8,7
    8 IF(OUTPUT(11))9,9,7
    7 NSTAT(IREP,5) = NSTAT(IREP,5) + 1
    9 RETURN
      END
```

```
      SUBROUTINE AGGREG(NSTAT,IREP,NTOT)
      DIMENSION NSTAT(100,5),NTOT(5)
      DO 1 I = 1,5
      NTOT(I) = 0
      DO 2 J = 1,IREP
    2 NTOT(I) = NTOT(I) + NSTAT(J,I)
      NTOT(I) = NTOT(I)/IREP
    1 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CMLTV ( XSTAT,YSTAT,NUMX,NUMY)
      DIMENSION XSTAT(500),YSTAT(500)
      DO 1 I=2,NUMX
    1 XSTAT(I) = XSTAT(I) + XSTAT(I-1)
      XSTAT(1)=0.
      DO 2 I=2,NUMY
    2 YSTAT(I)= YSTAT(I) + YSTAT(I-1)
      YSTAT(1)=0.
C     PRINT 10,(XSTAT(I),YSTAT(I),I=1,801)
C  10 FORMAT(1H1,(E15.8,10X,E15.8))
      RETURN
      END
```

```
      SUBROUTINE EFM                                                     0423
      END FILE 51                                                        0424
      RETURN                                                             0425
      END                                                                0426
```

```
      SUBROUTINE STP

        IDENT       STP                                                  0427
        ENTRY       STP                                                  0428
        EXT         EFM                                                  0429
STP     SLJ         **                                                   0430
        ENI         0                                                    0431
+       SLJ     1   AA                                                   0432
        SLJ         BB                                                   0433
AA      RTJ         EFM                                                  0434
        ENI         0                                                    0435
+       SLS         STP                                                  0436
BB      SLJ         STP                                                  0437
        END                                                              0438
```

APPENDIX XII

PROGRAM LSQRPLOT

On the pages which follow in this appendix is the program listing for program LSQRPLOT and is included here to demonstrate how the distribution information provided by program MINDEL1 may be utilized. The subroutines DRAW and LSCFWOP were copied from the U. S. Naval Postgraduate School Computer Facility Library.

```
      PROGRAM LSQRPLOT
      DIMENSION X(500),Y(500),XSTAT(500),YSTAT(500),FXPTS(10),FYPTS(10),
     1ITITLE(12)
      COMMON/BLO/X,Y,XSTAT,YSTAT
      REWIND 2
      READ TAPE 2,NUMX,NUMY,X,Y,FXPTS,FYPTS,NF,XMEANX,YMEANY,N
      READ TAPE 2,XSTAT,YSTAT
      KK = 3
      ITITLE(1) = 8H
      ITITLE(2) = 8H   KRUMM
      ITITLE(3) = 8H,T.G. AN
      ITITLE(4) = 8HD SNYDER
      ITITLE(5) = 8H,S.V.
      ITITLE(6) = 8H
      ITITLE(7) = 8H     MIN
      ITITLE(8) = 8HE FREQUE
      ITITLE(9) = 8HNCY DIST
      ITITLE(10) = 8HRIBUTION
      ITITLE(11) = 8H ON X-AX
      ITITLE(12) = 8HIS
      CALL DRAW(NUMX,X,XSTAT,0,0,4H    ,ITITLE,0.,0.,0,0,0,0,8,8,1,LAST)
      ITITLE(11) = 8H ON Y-AX
      CALL DRAW(NUMY,Y,YSTAT,0,0,4H    ,ITITLE,0.,0.,0,0,0,0,8,8,1,LAST)
      READ TAPE 2,XSTAT,YSTAT
      ITITLE(7) = 8H     MIN
      ITITLE(8) = 8HE CUMULA
      ITITLE(9) = 8HTIVE DIS
      ITITLE(10) = 8HTRIBUTIO
      ITITLE(11) = 8HN ON X-A
      ITITLE(12) = 8HXIS
      CALL DRAW(NUMX,X,XSTAT,0,0,4H    ,ITITLE,0.,0.,0,0,0,0,8,8,1,LAST)
      ITITLE(11) = 8HN ON Y-A
      CALL DRAW(NUMY,Y,YSTAT,0,0,4H    ,ITITLE,0.,0.,0,0,0,0,8,8,1,LAST)
      ITITLE(1) = 8HKRUMM AN
      ITITLE(2) = 8HD SNYDER
```

```
      ITITLE(3) = 8H                                                      00350
      ITITLE(4) = 8H      LE                                              00360
      ITITLE(5) = 8HAST SQUA                                              00370
      ITITLE(6) = 8HRES FIT                                               00380
      ITITLE(7) = 8HTO MINE                                               00390
      ITITLE(8) = 8HCUMULATI                                              00400
      ITITLE(9) = 8HVE DISTR                                              00410
      ITITLE(10) = 8HIBUTION                                              00420
      ITITLE(11) = 8HCURVE ON                                             00430
      ITITLE(12) = 8H X-AXIS                                              00440
      CALL LSCFWOP(X,XSTAT,NUMX,KK,0,1,1,4,0,1,1,0,0,.0000001,0,ITITLE)   00450
      ITITLE(12) = 8H Y-AXIS                                              00460
      CALL LSCFWOP(Y,YSTAT,NUMY,KK,0,1,1,4,0,1,1,0,0,.0000001,0,ITITLE)   00470
      IR=54137                                                            00490
      ITITLE(4)= 8H                                                       00491
      ITITLE(5) = 8HRANDOM M                                              00492
      ITITLE(6) = 8HINFFIELD                                              00493
      ITITLE(7) = 8H    RESU                                              00494
      ITITLE(8) = 8HLTING FR                                              00495
      ITITLE(9) = 8HOM OUTPU                                              00496
      ITITLE(10) = 8HT OF PRO                                             00497
      ITITLE(11) = 8HGRAM MIN                                             00498
      ITITLE(12) = 8HDEL                                                  00499
      CALL DRAW(NF,FXPTS,FYPTS,1,0,4H    ,ITITLE,2000.,2000.,0,0,0,0,8,8  00500
     1,0,LAST)                                                            00502
      CALL POSGEN(X,XSTAT,Y,YSTAT,IR,N,NUMX,NUMY,ITITLE)                  00505
      END                                                                 00510
```

```
      SUBROUTINE POSGEN(A,B,C,D,IR,N,NUMX,NUMY,ITITLE)
      DIMENSION A(500),B(500),C(500),D(500),XPOSIT(500),YPOSIT(500),
     1ITITLE(12)
      DO 100 J=1,N
      CALL RAN1(IR,RN)
      DO 1 I=1,NUMX
      IF(B(I)-RN)1,2,3
    1 CONTINUE
    2 XPOSIT(J)= A(I)
      GO TO 10
    3 FRAC = (B(I)-RN)/(B(I)-B(I-1))
      XPOSIT(J) = A(I-1) + (A(I)-A(I-1))*FRAC
   10 CALL RAN1(IR,RN)
      DO 4 I=1,NUMY
      IF(D(I)-RN)4,5,6
    4 CONTINUE
    5 YPOSIT(J)=C(I)
      GO TO 100
    6 FRAC = (D(I)-RN)/(D(I)-D(I-1))
      YPOSIT(J) = C(I-1) + (C(I)-C(I-1))*FRAC
  100 CONTINUE
      PRINT 200
  200 FORMAT(1H1,50X,17H RANDOM MINEFIELD // 35X,46H MINE NO.           X
     1 COORD             Y COORD //)
      DO 250 I=1,N
      PRINT 300,I,XPOSIT(I),YPOSIT(I)
  300 FORMAT(37X,I5,10X,F10.4,10X,F10.4)
  250 CONTINUE
      AN = FLOATF(N)
      DIV = AN/30.
      IDIV = XFIXF(DIV)
      NREM = N - 30*IDIV
      IF(NREM.EQ.0)50,60
   60 DO 61 I=1,IDIV
```

```
      CALL DRAW(30,XPOSIT,YPOSIT,2,2,4H    ,ITITLE,2000.,2000.,0,0,0,0,8
     1,8,0,LAST)
      LU = N - 30*I
      DO 62 J=1,LU
      XPOSIT(J) = XPOSIT(J+30)
   62 YPOSIT(J) = YPOSIT(J+30)
   61 CONTINUE
      IF(NREM.EQ.1)63,64
   63 XPOSIT(2) = XPOSIT(1)  $  YPOSIT(2) = YPOSIT(1)
      CALL DRAW(2,XPOSIT,YPOSIT,3,2,4H    ,ITITLE,2000.,2000.,0,0,0,0,8,
     18,0,LAST)
      GO TO 9000
   64 CALL DRAW(NREM,XPOSIT,YPOSIT,3,2,4H    ,ITITLE,2000.,2000.,0,0,0,0
     1,8,8,0,LAST)
      GO TO 9000
   50 DO 51 I=1,IDIV
      IF(I.EQ.IDIV)55,56
   56 CALL DRAW(30,XPOSIT,YPOSIT,2,2,4H    ,ITITLE,2000.,2000.,0,0,0,0,8
     1,8,0,LAST)
      LU = N - 30*I
      DO 52 J=1,LU
      XPOSIT(J) = XPOSIT(J+30)
   52 YPOSIT(J) = YPOSIT(J+30)
   51 CONTINUE
   55 CALL DRAW(30,XPOSIT,YPOSIT,3,2,4H    ,ITITLE,2000.,2000.,0,0,0,0,8
     1,8,0,LAST)
 9000 RETURN
      END
```

```
SUBROUTINE RAN1(IR,RN)
A=0.
B=1.
IR=3125*IR
IR=IR-(IR/67108864)*67108864
FY=FLOATF(IR)
RN=FY/67108864.*(B-A)+A
RETURN
END
```

```
      SUBROUTINE LSCFWOP(A,B,MM,KK,KOT,KIP,KAP,KOP,NOP,NIP,MTI,XBAR,GAMM00000002
     1A,TOL,MC,ITITLE)                                                  000    4
      DIMENSION VEC(3000,6),S(101),ALP(101),BETA(101),RHOSQ(101),XP(101)00000010
      DIMENSION A(500),B(500),ITITLE(12)                                00000020
      COMMON VEC,S,ALP,BETA,XP                                          00000 30
    2 FORMAT(1H1)                                                       00000110
   21 FORMAT(10I5)                                                      00000180
      DO 6 II=1,MM                                                      00000190
      VEC(II,1)=A(II)                                                   00000200
    6 VEC(II,2) = B(II)                                                 00000220
      CALL SHIFT(XBAR,GAMMA,MM)                                         00000270
      S1 = MM                                                           00000280
      DO 31 J = 1,MM                                                    00000290
      VEC(J,3) = 0.0                                                    00000300
   31 VEC(J,4) = 1.0                                                    00000310
      BETA(1) = 0.0                                                     00000320
      S3 = 0.0                                                          00000330
      DO 32 L = 1,MM                                                    00000340
   32 S3 = S3 + VEC(L,2)**2                                             00000350
      K2 = KK + 1                                                       00000360
      DO 302 I = 1,K2                                                   00000370
      S4 = 0.0                                                          00000380
      DO 33 J = 1,MM                                                    00000390
   33 S4 = S4 + VEC(J,2)*VEC(J,4)                                       00000400
      S(I) = S4/S1                                                      00000410
      S5 = S3-S(I)**2*S1                                                00000420
      IF(MM-I-1)305,305,301                                             00000430
  301 RHOSQ(I) = S5/FLOATF(MM-I-1)                                      00000440
      GO TO 303                                                         00000450
  305 RHOSQ(I) = S5                                                     00000460
  303 K1 = I -1                                                         00000470
      DO 34 K = 1,K1                                                    00000480
      IF(ABSF(RHOSQ(K)-RHOSQ(I))-TOL) 71,71,34                          00000490
   34 CONTINUE                                                          00000500
      IF(I - K2)35,72,72                                                00000510
```

```
 35 DO 36 N = 1,MM
 36 VEC(N,5) = VEC(N,1)*VEC(N,4)
    T1 = 0.0
    DO 37 JJJ = 1,MM
 37 T1 = T1 + VEC(JJJ,5)*VEC(JJJ,4)
    ALP(I+1) = T1/S1
    T2 = 0.0
    DO 38 M = 1,MM
    VEC(M,5) = (VEC(M,1)-ALP(I+1))*VEC(M,4)-BETA(I)*VEC(M,3)
    T2 = T2+VEC(M,5)**2
    VEC(M,3) = VEC(M,4)
 38 VEC(M,4) = VEC(M,5)
    BETA(I+1) = T2/S1
    S3 = S5
    S1 = T2
302 CONTINUE
 72 K3 = K2
    GO TO 40
 71 K3 = I
 40 CALL UNSHIFT(XBAR,GAMMA,MM)
    KGL= 2
    IF(KIP) 718,718,717
717 CALL POLK(K3,KAP)
718 IF(NOP) 420,719,719
719 DO 7000 J=1,MM
7000 VEC(J,5) = VEC(J,2)
    IF(NOP)420,405,407
407 PRINT 1001
1001 FORMAT(1H2/50H THE ORDINATE VALUES USING THE RECURRENCE FORMULAS)
    PRINT 2
    MC = MM
    GO TO 1002
405 CALL SHIFT(XBAR,GAMMA,MM)
    DO 406 N =1,MM
    VEC(N,2) = XP(1)
```

```
      K4 = K3 - 1                                                       00000870
      DO 406 K=1,K4                                                     00000880
  406 VEC(N,2) = VEC(N,2)*VEC(N,1) + XP(K+1)                            00000890
      CALL UNSHIFT(XBAR,GAMMA,MM)                                       00000900
      DO 7001 J=1,MM                                                    00000903
 7001 B(J) = VEC(J,2)                                                   00000905
      CALL DRAW(MM,A,B,0,0,4H    ,ITITLE,0.,0.,0,0,0,0,8,8,1,LAST)     00000907
      IF(MTI-K4) 4760,4760,420                                          00000910
 4760 PRINT 5,K4                                                        00000920
    5 FORMAT(1H2/73H THE ORDINATE VALUES AS EVALUATED BY GENERATING THE 00000930
     1POLYNOMIAL OF DEGREE I4/1H1)                                      00000940
      CALL XPRINT(MM,KOP)                                               00000950
C                                                                       0000 955
C STATEMENT NO. 420 USED TO READ IF(KOT)1327,1327,402                  00000960
C                                                                       0000 965
  420 IF(KOT)411,411,402                                                00000967
  402 READ 21,MC                                                        00000970
      PRINT 821                                                         00000980
  821 FORMAT(1H2/61H THE FOLLOWING ORDINATES ARE CALCULATED FOR THE NEW 00000990
     1ABSCISSAS)                                                        00001000
      KGL = 1                                                           00001010
      KOT = KOT - 1                                                     00001020
      READ   7  ,(VEC(J,1),J=1,MC)                                      00001025
    7 FORMAT(6F10.5)                                                    00001030
 1002 K2 = K3 - 1                                                       00001040
      NOP = 0                                                           00001050
      CALL SHIFT(XBAR,GAMMA,MC)                                         00001060
      DO 51 J = 1,MC                                                    00001070
      VEC(J,2) = 0.0                                                    00001080
      VEC(J,3) = 0.0                                                    00001090
   51 VEC(J,4) = 1.0                                                    00001100
      DO 502 I = 1,K3                                                   00001110
      DO 52 J = 1,MC                                                    00001120
      VEC(J,2) = VEC(J,2) + S(I)*VEC(J,4)                               00001130
      IF(I -K3)503,52,52                                                00001140
```

```
503  P2 = (VEC(J,1)-ALP(I+1))*VEC(J,4) - BETA(I)*VEC(J,3)
     VEC(J,3) = VEC(J,4)
     VEC(J,4) = P2
  52 CONTINUE
     CALL UNSHIFT(XBAR,GAMMA,MC)
     JJ2 = I - 1
     IF(NIP)1003,1003,1004
1004 IF(I-K3)502,1003,502
1003 IF(MTI-JJ2) 5436,5436,502
5436 PRINT 643,JJ2
 643 FORMAT(////66H THE FOLLOWING VALUES WERE CALCULATED USING A POLYNO
    1MIAL OF DEGREE I4)
     GO TO (705,799), KSL
 799 CALL XPRINT(MC,KOP)
     GO TO 502
 705 PRINT 707
 707 FORMAT(/3(8X,29H ABSCISSA          ORDINATE    ))
     MC1 = MC - 2
     DO 701 K = 1,MC1,3
     L = K
 701 PRINT 23,VEC(K,1),VEC(K,2),VEC(K+1,1),VEC(K+1,2),VEC(K+2,1),
    1  VEC(K+2,2)
     IF(L+1-MC1)703,702,502
 702 PRINT 23,VEC(MC,1),VEC(MC,2)
     GO TO 502
 703 PRINT 23,VEC(MC-1,1),VEC(MC-1,2),VEC(MC,1),VEC(MC,2)
 502 CALL SHIFT(XBAR,GAMMA,MC)
5002 CONTINUE
  23 FORMAT(3(5X,1PE14.4,3X,1PE14.4))
C
C  THE NEXT STATEMENT USED TO READ IF(KOT)1327,1327,402
C
 411 CONTINUE
     END
```

```
      SUBROUTINE POLK(KQ,KR)
      DIMENSION COEF(100,100),ALP(101),BETA(101),S(101),XP(101),
     1 DUM(8000)
      COMMON DUM,COEF,S,ALP,BETA,XP
      DO 31 I = 1,KQ
      COEF(I,1) = 1.0
   31 COEF(I,I+1) = 0.0
      DO 32 I = 2,KQ
   32 COEF(I,2) = COEF(I-1,2) - ALP(I)
       DO 33 J = 3,KQ
      DO 33 I = J,KQ
   33 COEF(I,J) = COEF(I-1,J) - ALP(I)*COEF(I-1,J-1)  -
     1  BETA(I-1)*COEF(I-2,J-2)
      DO 34 I = 1,KQ
      DO 34 J = 1,I
   34 COEF(I,J) = COEF(I,J)*S(I)
   17 FORMAT(///46H THE COEFFICIENTS FOR THE POLYNOMIAL OF DEGREE I4/(/
     1 1PE20.10,1PE20.10,1PE20.10,1PE20.10,1PE20.10,1PE20.10))
      DO 26 N = 1,KQ
      MKM = N - 1
      XP(N) = 0.0
      DO 531 I=1,N
  531 XP(N) = COEF(I,I) + XP(N)
      IF(MKM) 400,350,400
  400 DO 35 J=1,MKM
      XP(N-J) = 0.0
      M = J + 1
      DO 35 I = M,N
   35 XP(N-J) = COEF(I,I-J) + XP(N-J)
  350 IF(KR) 21,26,23
   21 MN1 = N - 1
      PRINT 17,MN1,(XP(L),L=1,N)
      GO TO 26
   23 IF(N-KQ)26,21,26
   26 CONTINUE
      END
```

```
      SUBROUTINE SHIFT(X,Y,MQ)
      DIMENSION VEC(3000,6),S(101),ALP(101),BETA(101),XP(101)
      COMMON VEC,S,ALP,BETA,XP
      DO 31 I=1,MQ
   31 VEC(I,1)=(VEC(I,1)-X)/(1.0-Y)
      END
```

```
      SUBROUTINE UNSHIFT(X,Y,MQ)
      DIMENSION VEC(3000,6),S(101),ALP(101),BETA(101),XP(101)
      COMMON VEC,S,ALP,BETA,XP
      DO 31 I=1,MQ
   31 VEC(I,1)=VEC(I,1)*(1.0-Y) + X
      END
```

```
      SUBROUTINE XPRINT(NUM,KOP)
      DIMENSION VEC(3000,6),S(101),ALP(101),BETA(101),XP(101)
      COMMON VEC,S,ALP,BETA,XP
      YBAR = 0.0
      YAV  = 0.0
      YSQ = 0.0
      YMAX = 0.0
      DO 950 J=1,NUM
      VEC(J,6)= VEC(J,2)-VEC(J,5)
      T = ABSF(VEC(J,6))
      YBAR = YBAR + T
      YSQ = YSQ + T*T
      IF(YMAX-T) 970,950,950
  970 YMAX = T
  950 YAV = YAV + VEC(J,6)
      YBAR = YBAR/FLOATF(NUM)
      YSQ = SQRTF(YSQ/FLOATF(NUM))
      GO TO (900,902,904,905),KOP
  904 PRINT 966
  966 FORMAT(////9X,8HORIGINAL,11X,8HCOMPUTED,11X,8HORDINATE/9X,8HABSCIS
     1SA,11X,8HORDINATE,10X,11HDIFFERENCES//)
      PRINT 965,(VEC(J,1),VEC(J,2),VEC(J,6),J=1,NUM)
  965 FORMAT(3(5X,1PE14.4))
      GO TO 900
  902 PRINT 964
  964 FORMAT(////9X,8HORIGINAL,11X,8HORIGINAL,11X,8HORDINATE/9X,8HABSCIS
     1SA,11X,8HORDINATE,10X,11HDIFFERENCES//)
      PRINT 965,(VEC(J,1),VEC(J,5),VEC(J,6),J=1,NUM)
      GO TO 900
  905 PRINT 962
  962 FORMAT(////9X,8HORIGINAL,11X,8HORIGINAL,11X,8HCOMPUTED,11X,8HORDIN
     1ATE/9X,8HABSCISSA,11X,8HORDINATE,11X,8HORDINATE,10X,11HDIFFERENCES
     2//)
      PRINT 961,(VEC(J,1),VEC(J,5),VEC(J,2),VEC(J,6),J=1,NUM)
  961 FORMAT(4(5X,1PE14.4))
```

```
 900 PRINT 960, YAV, YBAR , YSQ , YMAX                                  00002300
 960 FORMAT(////53H SUM OF (COMPUTED ORDINATE MINUS ORIGINAL ORDINATE)=00002310
   1 1PE16.8//17H ERROR NORM L1 = 1PE16.8//17H ERROR NORM L2 = 1PE16.800002320
   2 //25H ERROR NORM L-INFINITY = 1PE16.8)                              00002330
     GO TO (1900,2000,2000,2000),KOP                                     00002340
1900 PRINT 4                                                             00002350
   4 FORMAT(1H2)                                                         00002360
     RETURN                                                              00002370
2000 PRINT 5                                                             00002380
   5 FORMAT(1H1)                                                         00002390
        END                                                              000240
```

APPENDIX XIII

SAMPLE RUN

On the succeeding pages of this appendix appears the printed output of programs MINDEL and MINDEL1. The particular runs shown were chosen on the basis of the number of program features which were demonstrated, RUN NO. 2

SUMMARY NARRATIVE

TIME	EVENT
160830.	SUBMARINE NO. 1 ARRIVES AT IP FOR LEG NO. 1
160840.2	MINE NO. 149 LAYED
160848.5	MINE NO. 150 NOT LAYED DUE TO EXCESSIVE TIME DELAY
160851.6	MINE NO. 151 LAYED
160901.5	MINE NO. 152 LAYED
160912.5	MINE NO. 153 LAYED
160922.	MINE NO. 154 LAYED
160935.	SUB NO. 1 ARRIVES AT IP FOR LEG NO. 1
160959.2	SUB NO. 1 ARRIVES AT IP FOR LEG NO. 2
161000.5	MINE NO. 155 LAYED
161004.3	MINE NO. 156 LAYED
161006.2	MINE NO. 157 LAYED
161009.1	MINE NO. 158 LAYED
161011.5	MINE NO. 159 LAYED
161018.4	SUB NO. 1 ARRIVES AT IP FOR LEG NO. 2
180936.1	SUBMARINE NO. 2 ARRIVES AT IP FOR LEG NO. 3
180942.2	MINE NO. 160 LAYED
180945.4	MINE NO. 161 LAYED
180948.2	MINE NO. 162 LAYED
180951.1	MINE NO. 163 LAYED
180953.5	MINE NO. 164 LAYED
181000.3	SUB NO. 2 SUSPENDS OPS DUE TO ERRONEOUS KNOWLDEGE OF DETECTION.
200244.9	SUB NO. 2 RESUMES OPS.
200302.1	SUB NO. 2 ARRIVES AT IP FOR LEG NO. 4
200305.7	MINE NO. 165 LAYED
200308.2	MINE NO. 166 LAYED
200311.9	MINE NO. 167 LAYED
200315.4	SUB NO. 2 ARRIVES AT IP FOR LEG NO. 4
200730.3	SHIP NO. 1 ARRIVES AT IP FOR LEG NO. 1

```
200731.5 MINE NO.  64 LAYED
200732.6 MINE NO.  65 LAYED
200733.6 MINE NO.  66 LAYED
200734.7 MINE NO.  67 LAYED
200735.7 MINE NO.  68 LAYED
200736.6 MINE NO.  69 LAYED
200737.6 MINE NO.  70 LAYED
200738.7 MINE NO.  71 LAYED
200739.6 MINE NO.  72 LAYED
200740.6 MINE NO.  73 LAYED
200741.9 MINE NO.  74 LAYED
200743.0 MINE NO.  75 LAYED
200743.9 MINE NO.  76 LAYED
200745.0 MINE NO.  77 LAYED
200746.0 MINE NO.  78 LAYED
200746.9 SHIP NO.   1 DAMAGED. NAVIGATIONAL ERROR DOUBLED.
200748.7 MINE NO.  79 LAYED
200750.8 MINE NO.  80 LAYED
200751.3 MINE NO.  81 LAYED
200752.9 MINE NO.  82 LAYED
200753.8 MINE NO.  83 LAYED
200754.8 MINE NO.  84 LAYED
200755.6 SHIP NO.   1 ARRIVES AT TP FOR LEG NO.   1

200756.9 SHIP NO.   1 ARRIVES AT IP FOR LEG NO.   2
200759.3 MINE NO.  85 LAYED
200801.9 MINE NO.  86 LAYED
200804.6 MINE NO.  87 LAYED
200807.2 MINE NO.  88 LAYED
200810.1 MINE NO.  89 LAYED
200812.6 MINE NO.  90 LAYED
200815.5 MINE NO.  91 LAYED
200818.2 MINE NO.  92 LAYED
200818.9 SHIP NO.   1 ARRIVES AT TP FOR LEG NO.   2

200745.3 SHIP NO.   2 ARRIVES AT IP FOR LEG NO.   3
200747.1 SHIP NO.   2 DAMAGED. ABORTS MISSION. MINES REMAINING ON BOARD ARE
                                                                        93
                                                                        94
                                                                        95
                                                                        96
                                                                        97
                                                                        98
                                                                        99
                                                                       100
                                                                       101
                                                                       102
                                                                       103
                                                                       104
                                                                       105
                                                                       106
                                                                       107
                                                                       108
                                                                       109
```

110
111
112
113

```
200900.0 SHIP NO.   3 ARRIVES AT IP FOR LEG NO.   5
200902.6 MINE NO. 114 LAYED
200905.1 MINE NO. 115 LAYED
200907.5 MINE NO. 116 LAYED
200910.3 MINE NO. 117 LAYED
200912.8 MINE NO. 118 LAYED
200915.4 MINE NO. 119 LAYED
200917.9 MINE NO. 120 LAYED
200920.3 MINE NO. 121 LAYED
200923.1 MINE NO. 122 LAYED
200925.5 MINE NO. 123 LAYED
200928.2 MINE NO. 124 LAYED
200930.5 SHIP NO.   3 DAMAGED. NAVIGATIONAL ERROR DOUBLED.
200930.6 MINE NO. 125 LAYED
200933.1 MINE NO. 126 LAYED
200935.1 SHIP NO.   3 ARRIVES AT TP FOR LEG NO.   5

200936.7 SHIP NO.   3 ARRIVES AT IP FOR LEG NO.   6
200939.4 MINE NO. 124 LAYED
200943.0 MINE NO. 128 LAYED
200946.8 MINE NO. 129 LAYED
200950.1 MINE NO. 130 LAYED
200954.0 MINE NO. 131 LAYED
200957.7 MINE NO. 132 LAYED
201000.9 MINE NO. 133 LAYED
201004.4 MINE NO. 134 LAYED
201007.8 MINE NO. 135 LAYED
201009.9 MINE NO. 136 LAYED
201012.9 SHIP NO.   3 ARRIVES AT TP FOR LEG NO.   6

201015.6 SHIP NO.   3 ARRIVES AT IP FOR LEG NO.   7
201019.1 MINE NO. 137 LAYED
201021.8 MINE NO. 138 LAYED
201024.8 MINE NO. 139 LAYED
201027.9 MINE NO. 140 LAYED
201030.6 MINE NO. 141 LAYED
201033.7 MINE NO. 142 LAYED
201036.9 MINE NO. 143 LAYED
201039.7 MINE NO. 144 LAYED
201042.9 MINE NO. 145 LAYED
201045.9 MINE NO. 146 LAYED
201049.2 MINE NO. 147 LAYED
201050.5 MINE NO. 148 LAYED
```

```
201052.2 SHIP NO.   5 ARRIVES AT IP FOR LEG NO.   7

221550.5 A/C NO.    1 ARRIVES AT IP FOR LEG NO.   1
221551.4 MINE NO.   1 LAYED
221551.5 MINE NO.   2 LAYED
221551.6 MINE NO.   3 LAYED
221551.7 MINE NO.   4 LAYED
221551.8 MINE NO.   5 LAYED
221551.9 MINE NO.   6 LAYED
221552.0 MINE NO.   7 LAYED
221552.1 MINE NO.   8 LAYED
221553.7 A/C NO.    1 ARRIVES AT TP FOR LEG NO.   1

221554.1 A/C NO.    2 ARRIVES AT IP FOR LEG NO.   2
221555.0 MINE NO.   9 LAYED
221555.1 MINE NO.  10 LAYED
221555.2 MINE NO.  11 LAYED
221555.3 MINE NO.  12 LAYED
221555.4 MINE NO.  13 LAYED
221555.5 MINE NO.  14 LAYED
221555.6 MINE NO.  15 LAYED
221555.7 MINE NO.  16 LAYED
221557.3 A/C NO.    2 ARRIVES AT TP FOR LEG NO.   2

221557.8 A/C NO.    3 ARRIVES AT IP FOR LEG NO.   3
221558.7 MINE NO.  17 LAYED
221558.8 MINE NO.  18 LAYED
221558.9 MINE NO.  19 LAYED
221559.0 MINE NO.  20 LAYED
221559.1 MINE NO.  21 LAYED
221559.2 MINE NO.  22 LAYED
221559.3 MINE NO.  23 LAYED
221559.7 MINE NO.  24 LAYED
221601.0 A/C NO.    3 ARRIVES AT TP FOR LEG NO.   3

221603.0 A/C NO.    4 ARRIVES AT IP FOR LEG NO.   4
221603.7 A/C NO.    4 ATTRITED. MINES REMAINING ON BOARD ARE
                                                         25
                                                         29
                                                         26
                                                         30
                                                         27
                                                         31
                                                         28
                                                         32

221607.3 A/C NO.    5 ARRIVES AT IP FOR LEG NO.   5
221608.2 MINE NO.  33 DID NOT RELEASE
221608.3 MINE NO.  34 DID NOT RELEASE
221608.4 MINE NO.  35 LAYED
221608.5 MINE NO.  36 LAYED
221608.6 MINE NO.  37 IS BLOCKED BY PRIOR RELEASE FAILURE
```

```
221608.7 MINE NO.  38 IS BLOCKED BY PRIOR RELEASE FAILURE
221608.8 MINE NO.  39 DID NOT RELEASE
221608.9 MINE NO.  40 DID NOT RELEASE
221610.5 A/C NO.    5 ARRIVES AT TP FOR LEG NO.   5

221611.9 A/C NO.    6 ARRIVES AT IP FOR LEG NO.   6
221612.8 MINE NO.  41 LAYED
221612.9 MINE NO.  42 DID NOT RELEASE
221613.0 MINE NO.  43 LAYED
221613.1 MINE NO.  44 LAYED
221613.2 MINE NO.  45 LAYED
221613.3 MINE NO.  46 IS BLOCKED BY PRIOR RELEASE FAILURE
221613.4 MINE NO.  47 LAYED
221613.5 MINE NO.  48 DID NOT RELEASE
221615.1 A/C NO.    6 ARRIVES AT TP FOR LEG NO.   6

221612.2 A/C NO.    7 ARRIVES AT IP FOR LEG NO.   7
221613.0 MINE NO.  49 LAYED
221613.1 MINE NO.  50 LAYED
221613.1 MINE NO.  51 DID NOT RELEASE
221613.2 MINE NO.  52 DID NOT RELEASE
221613.3 MINE NO.  53 LAYED
221613.4 MINE NO.  54 LAYED
221613.5 MINE NO.  55 LAYED
221614.8 A/C NO.    7 ARRIVES AT TP FOR LEG NO.   7

221617.3 A/C NO.    7 ARRIVES AT IP FOR LEG NO.   8
221618.1 MINE NO.  56 LAYED
221618.1 MINE NO.  57 IS BLOCKED BY PRIOR RELEASE FAILURE
221618.2 MINE NO.  58 IS BLOCKED BY PRIOR RELEASE FAILURE
221618.3 MINE NO.  59 LAYED
221618.4 MINE NO.  60 LAYED
221618.5 MINE NO.  61 LAYED
221618.6 MINE NO.  62 LAYED
221618.7 MINE NO.  63 IS BLOCKED BY PRIOR RELEASE FAILURE
221620.9 A/C NO.    7 ARRIVES AT TP FOR LEG NO.   8
```

INPUT TO MINE DELIVERY PHASE

FIELD DATA

THE X REFERENCE POSITION IS -121.9745 DEGREES

THE Y REFERENCE POSITION IS 36.6287 DEGREES

FIELD PERIMETER POINTS

XCOORD	YCOORD
1743.5314	829.2722
1743.5314	4045.2309
9825.6956	6917.3448
15626.6038	6917.3448
14648.9228	3842.9694
10281.9468	3842.9694
11357.3960	1031.5338
8489.5313	0
7430.3767	2851.8879
1743.5314	829.2722

VEHICLE ARRIVAL LIST

TOA	VEHICLE TYPE	VEHICLE NUMBER	TOTAL NO.OF LEGS ASSIGNED	NO.OF BOMB RACKS	LEGS ASSIGNED (CODED)					
160830.0	2	1	2	0	1002000	0	0	0	0	0
180936.0	1	2	2	0	3004000	0	0	0	0	0
200730.5	10	1	2	0	1002000	0	0	0	0	0
200745.3	10	2	2	C	3004000	0	0	0	0	0
200900.0	11	3	3	0	5006007	0	0	0	0	0
221550.5	100	1	1	4	1000000	0	0	0	0	0
221554.1	100	2	1	4	2000000	0	0	0	0	0
221557.8	100	3	1	4	3000000	0	0	0	0	0
221603.0	101	4	1	4	4000000	0	0	0	0	0
221607.3	101	5	1	4	5000000	0	0	0	0	0
221611.9	101	6	1	4	6000000	0	0	0	0	0
221612.2	102	7	2	6	7008000	0	0	0	0	0

AIRCRAFT CHARACTERISTICS LIST

VEHICLE TYPE	XSIT SPEED	M/L SPEED	M/L ALTITUDE	PROB OF MINE RELEASE	PROB OF SURVIVAL OVER OBJECTIVE AREA
100	225	200	1000	.88	.80
101	250	200	1000	.90	.76
102	400	250	5000	.94	.85

AIRCRAFT LEG DESCRIPTION LIST

LEG NO.	NO.OF MINES THIS LEG	AIRCRAFT INITIAL POSIT XCOORD	AIRCRAFT INITIAL POSIT YCOORD	MINE NO.	MINE INTENDED POSITION XCOORD	MINE INTENDED POSITION YCOORD	AIRCRAFT TERMINAL POINT XCOORD	AIRCRAFT TERMINAL POINT YCOORD
1	8	21671.973	6755.536					
				1	15610.309	6755.536		
				2	14942.227	6755.536		
				3	14241.556	6755.536		
				4	13492.000	6755.536		
				5	12840.213	6755.536		
				6	12139.541	6755.536		
				7	11458.870	6755.536		
				8	10721.903	6755.536		
							195.536	9526.519
2	8	21313.449	6411.691					
				9	15251.826	6411.691		
				10	14388.208	6411.691		
				11	13806.778	6411.691		
				12	13231.285	6411.691		
				13	12530.614	6411.691		
				14	11895.121	6411.691		
				15	11096.681	6411.691		
				16	10412.304	6411.691		
							195.536	9526.519
3	8	21460.1[illegible]	6027.394					
				17	15333.300	6027.394		
				18	14632.628	6027.394		
				19	13948.251	6027.394		
				20	13296.464	6027.394		
				21	12612.087	6027.394		
				22	11911.415	6027.394		
				23	11243.333	6027.394		
				24	8945.783	6027.394		
							195.536	9526.519
4	8	21174.208	5582.419					
				25	15007.406	5582.419		
				26	14323.029	5582.419		
				27	13638.652	5582.419		

				28	12937.951	5582.419		
				29	12221.014	5582.419		
				30	11569.227	5582.419		
				31	10808.556	5582.419		
				32	10200.473	5582.419		
							195.536	9526.519
5	8	21036.440	5198.122	33	15105.174	5198.122		
				34	14437.092	5198.122		
				35	13687.536	5198.122		
				36	13019.454	5198.122		
				37	12335.077	5198.122		
				38	11666.995	5198.122		
				39	10598.913	5198.122		
				40	10265.652	5198.122		
							195.536	9526.519
6	8	20840.903	4793.599	41	14746.691	4793.599		
				42	14078.609	4793.599		
				43	13361.643	4793.599		
				44	12660.971	4793.599		
				45	12009.184	4793.599		
				46	11324.807	4793.599		
				47	10591.546	4793.599		
				48	9507.169	4793.599		
							195.536	9526.519
7	7	20938.672	4409.302	49	14359.324	4409.302		
				50	13671.241	4409.302		
				51	12986.865	4409.302		
				52	12286.193	4409.302		
				53	11585.522	4409.302		
				54	10901.145	4409.302		
				55	10200.473	4409.302		
							195.536	9526.519
8	8	20808.314	3984.553	56	14665.217	3984.553		
				57	13964.546	3984.553		
				58	13263.874	3984.553		
				59	12530.614	3984.553		
				60	11829.942	3984.553		
				61	11145.565	3984.553		
				62	10428.599	3984.553		
				63	9679.044	3984.553		

195.536 9526.519

BOMB RACK ARRAY

A/C NO.	BOMB RACK NC. CNE	TWO	THREE	FCUR	FIVE	SIX
1	5001	6002	7003	8004	0	0
2	13009	14010	15011	16012	0	0
3	21017	22018	23019	24020	0	0
4	29025	30026	31027	32028	0	0
5	37033	38034	39035	40036	0	0
6	45041	46042	47043	48044	0	0
7	61055049	62056050	63057051	58052	59053	60054

AIRCRAFT MINE CHARACTERISTICS LIST

MINE TYPE (II)	A	B	C	D	E	F	G	H	I	J	K	L	M
1	.90	700	850	.1	.1	.6	.6	.5	3	0	0	0	.9
2	.88	650	800	.1	.1	.6	.7	.5	3	0	0	0	.9
3	.91	750	900	.1	.2	.6	.8	.4	3	0	0	0	.9
4	.94	800	950	.1	.1	.6	.6	.5	3	0	0	0	.9
5	.92	640	790	.1	.2	.6	.6	.5	3	0	0	0	.9
6	.90	700	850	.2	.2	.6	.8	.6	3	0	0	0	.9
7	.89	750	900	.1	.2	.6	.7	.5	3	0	0	0	.9
8	.90	750	900	.1	.2	.6	.7	.5	3	0	0	0	.9
9	.92	680	830	.1	.1	.6	.6	.4	3	0	0	0	.9
10	1.00	750	750	.1	.1	.4	.4	.4	3	0	0	0	.9
11	.93	800	950	.1	.1	.6	.6	.6	3	0	0	0	.9
12	.94	750	900	.1	.1	.6	.7	.5	3	0	0	0	.9
13	.93	700	850	.1	.1	.6	.7	.5	2	0	.9	.9	.9
14	.90	600	750	.1	.2	.6	.6	.6	3	0	0	0	.9
15	.87	650	800	.1	.1	.6	.6	.5	3	0	0	0	.9
16	.91	650	800	.1	.2	.5	.6	.5	3	0	0	0	.9
17	.88	600	750	.1	.2	.5	.6	.4	3	0	0	0	.9
18	.96	750	900	.1	.2	.6	.7	.4	3	0	0	0	.9
19	.92	800	950	.1	.2	.6	.7	.6	3	0	0	0	.9
20	.95	800	950	.1	.2	.6	.6	.5	3	0	0	0	.9
21	.91	750	900	.1	.2	.6	.7	.5	3	0	0	0	.9
22	.94	750	900	.1	.2	.6	.7	.5	3	0	0	0	.9
23	.88	650	800	.2	.2	.6	.8	.5	3	0	0	0	.9
24	.89	700	850	.1	.2	.6	.7	.4	3	0	0	0	.9

A = PROB OF CHUTE DEPLOYMENT
B = CEP FOR 3K FT,CHUTE DEPLOYS
C = CEP FOR 3K FT,CHUTE DOES NOT DEPLOY
D = PROB OF WATER IMPACT DAMAGE,CHUTE DEPLOYS
E = PROB OF WATER IMPACT DAMAGE,CHUTE DOES NOT DEPLOY
F = PROB OF IMPACT DAMAGE ON THE HARDEST BOTTOM,GIVEN DEPTH LESS THAN 20FT AND CHUTE DEPLOYS
G = PROB OF IMPACT DAMAGE ON HARDEST BOTTOM,GIVEN DEPTH LESS THAN 20FT AND CHUTE DOES NOT DEPLOY
H = PROB OF BURYING IN SOFTEST BOTTOM
I = INDICATOR OF MOOR OR BOTTOM TYPE
J = NWL TYPE IF BOTTOM MINE DOES NOT BURY/BURIES
K = PROB OF CASE/ANCHOR SEPARATION
L = PROB OF FULL ANCHOR CABLE DEPLOYMENT
M = PROB MINE OPERATES,GIVEN IT HAS NOT BEEN DAMAGED (RELIABILITY)

SHIP CHARACTERISTIC LIST

VEHICLE TYPE	XSIT SPEED	M/L SPEED	NAVIGATIONAL ERROR LEAST	NAVIGATIONAL ERROR AVERAGE	NAVIGATIONAL ERROR GREATEST	PROB OF MINE RELEASE	MAX TIME DELAY	PROB OF DAMAGE FOR FIRST HALF HOUR IN MLOA
10	25	12	25	100	200	.9	.2	.3
11	20	8	15	75	150	.9	.3	.4

SHIP LEG DESCRIPTION LIST

LEG NO.	NO.OF MINES THIS LEG	SHIP INITIAL POSIT XCOORD	SHIP INITIAL POSIT YCOORD	MINE NO.	MINE INTENDED POSITION XCOORD	MINE INTENDED POSITION YCOORD	SHIP TERMINAL POINT XCOORD	SHIP TERMINAL POINT YCOORD
1	21	1743.531	970.855					
				64	2134.604	1112.439		
				65	2525.676	1334.926		
				66	2916.749	1395.605		
				67	3307.821	1577.640		
				68	3698.894	1678.771		
				69	4057.377	1820.354		
				70	4415.860	1982.163		
				71	4823.227	2164.199		
				72	5165.416	2265.329		
				73	5556.488	2427.139		
				74	6045.329	2548.496		
				75	6468.990	2690.079		
				76	6811.179	2811.435		
				77	7267.430	2953.019		
				78	7625.913	3114.828		
				79	7968.101	4166.588		
				80	8408.058	3438.446		
				81	8750.246	3580.029		
				82	9190.203	3640.708		
				83	9532.391	3842.969		
				84	9907.169	4004.779		
							10200.473	4045.231
2	8	9874.580	4449.754					
				85	8913.193	4166.588		
				86	7951.807	3802.517		
				87	6925.242	3397.994		
				88	5914.971	3054.149		
				89	4855.816	2629.400		
				90	3861.840	2326.008		
				91	2753.802	1941.711		
				92	1743.531	1577.640		
							1450.227	1476.509
3	8	1336.164	1820.354					

				93	2525.676	2143.972		
				94	3666.304	2629.400		
				95	4741.753	3013.697		
				96	5817.203	3397.994		
				97	6957.831	3822.743		
				98	8049.575	4207.040		
				99	9108.730	4611.563		
				100	9695.338	4793.599		
							10347.126	5218.348
4	13	10721.903	5400.383					
				101	10086.410	5157.670		
				102	9532.391	4975.634		
				103	8848.014	4753.146		
				104	8131.048	4571.111		
				105	7495.556	4247.492		
				106	6811.179	4045.231		
				107	6273.454	3802.517		
				108	5637.961	3580.029		
				109	4969.879	3357.542		
				110	4334.386	3033.923		
				111	3666.304	2811.435		
				112	3030.812	2629.400		
				113	2346.435	2427.139		
							1727.236	2204.651
5	13	1303.575	2609.174					
				114	1955.362	2851.888		
				115	2590.855	3074.376		
				116	3275.232	3317.089		
				117	3894.430	3690.255		
				118	4546.217	3782.291		
				119	5198.005	4025.005		
				120	5849.792	4227.266		
				121	6468.990	4449.754		
				122	7153.367	4773.372		
				123	7772.565	4955.408		
				124	8456.942	5198.122		
				125	9076.140	5420.609		
				126	9695.338	5643.097		
							10200.473	5825.133
6	10	10200.473	6270.108					
				124	9516.097	6027.394		
				128	8603.594	5703.775		
				129	7642.208	5319.479		
				130	6762.295	5177.896		

				131	5784.613	4773.372		
				132	4904.700	4308.171		
				133	4106.261	3964.326		
				134	3242.642	3620.482		
				135	2362.729	3317.089		
				136	1825.005	3155.280		
							1075.449	2892.340
7	12	1385.048	3559.803					
				137	2281.256	3842.969		
				138	2998.222	4045.231		
				139	3747.778	4348.623		
				140	4529.923	4611.563		
				141	5230.594	4854.277		
				142	5980.150	5218.348		
				143	6811.179	5461.062		
				144	7479.261	5804.906		
				145	8310.290	6047.620		
				146	9076.140	6351.013		
				147	9890.874	6674.631		
				148	10216.768	6795.988		
							10673.019	6735.310

SHIP MINE CHARACTERISTIC LIST

MINE TYPE (II)	A	B	C	D	E	F	G
1	.2	.4	2	0	.9	.9	1.0
2	.1	.4	2	0	.9	.9	.9
3	.1	.4	2	0	.9	.9	1.0
4	.1	.4	2	0	.9	.9	.9
5	.1	.4	2	0	.9	.9	.9
6	.2	.4	2	0	1.0	.9	1.0
7	.2	.4	5	0	1.0	.9	1.0
8	.2	.4	2	0	.9	.9	.9
9	.1	.4	3	0	0	0	.9
10	.2	.4	1	0	.9	.9	.9

A = PROB OF DAMAGE ON HARDEST BOTTOM,GIVEN DEPTH LESS THAN 20FT
B = PROB OF BURYING IN SOFTEST BOTTOM
C = INDICATOR OF MOOR OR BOTTOM TYPE
D = NWL TYPE IF BOTTOM MINE DOESNOT BURY/BURIES
E = PROB OF CASE/ANCHOR SEPARATION
F = PROB OF FULL ANCHOR CABLE DEPLOYMENT
G = PROB MINE OPERATES,GIVEN IT HAS NOT BEEN DAMAGED (RELIABILITY)

SUBMARINE CHARACTERISTIC LIST

VEHICLE TYPE	XSIT SPEED	M/L SPEED	NAVIGATION ERROR BEST	AVG	GREATEST	PMR	FTDM	PD	PKD/D	PKD/ND	PSO/KD	PR/SO	PR/UA	PA/D	PSA/A	D(100)
1	12	4	25	100	250	.9	1.6	.2	.9	.1	1.0	1.0	0	.8	.5	10000
2	15	5	15	75	200	.9	1.5	.2	.9	.1	0	0	1.0	.9	.4	10000

PMR = PROB MINE IS READY AT FIRING TIME
FTDM = FIRING TIME DELAY (MAXIMUM)
PKD/D = PROB SUBMARINE HAS KNOWLEDGE OF DETECTION,GIVEN DETECTION HAS OCCURRED
PKD/ND = PROB SUBMARINE THINKS DETECTION HAS OCCURRED,GIVEN NO DETECTION
PSO/KD = PROB SUBMARINE SUSPENDS OPS,GIVEN IT HAS KNOWLEDGE OF DETECTION
PR/SD = PROB SUBMARINE RETURNS,GIVEN IT HAD SUSPENDED OPS
PR/UA = PROB SUBMARINE RETURNS,GIVEN UNSUCCESFUL ATTACK
PA/D = PROB OF ATTACK,GIVEN DETECTION
PSA/A = PROB OF SUCCESSFUL ATTACK,GIVEN ATTACK
D(100) = DISTANCE FROM MINEFIELD PERIMETER TO 100 FATHOM CURVE

DATE-TIME FOR COMPLETION OF SUBMARINE OPERATIONS IS 200730.5

SUBMARINE LEG DESCRIPTION LIST

LEG NO.	NO. OF MINES THIS LEG	SUB INITIAL POSIT XCOORD	SUB INITIAL POSIT YCOORD	MINE NO.	SUB FIRING POSIT XCOORD	SUB FIRING POSIT YCOORD	MINE INTENDED POSITION XCOORD	MINE INTENDED POSITION YCOORD	SUB TERMINAL POINT YCOORD	SUB TERMINAL POINT YCOORD
1	6	7137.072	6027.394							
				149	7919.217	4126.136	8261.406	1152.891		
				150	8228.817	3296.863	8652.478	242.714		
				151	8473.237	2629.400	9271.676	566.332		
				152	9825.696	3600.255	9890.874	788.820		
				153	8000.691	4025.005	10558.957	1334.926		
				154	9548.686	4389.076	10705.609	2386.686		
									8701.362	6411.691
2	5	10526.367	2953.019							
				155	10119.000	2770.983	10119.000	2770.983		
				156	9695.338	2568.722	9695.338	2568.722		
				157	9320.560	2346.234	9320.560	2346.234		
				158	8896.899	2103.520	8896.899	2103.520		
				159	8456.942	1961.937	8456.942	1961.937		
									8098.459	1719.223
3	5	7577.029	7787.070							
				160	7902.923	6998.249	7642.208	2932.792		
				161	8098.459	6634.179	7805.154	2568.722		
				162	8114.754	6209.429	8098.459	2083.294		
				163	8228.817	5885.811	8603.594	2609.174		
				164	8277.700	5521.740	8440.647	2892.340		
									8717.657	4449.754
4	3	9043.551	3357.542							
				165	9532.391	3296.863	9532.391	3296.863		
				166	9858.285	3256.411	9858.285	3256.411		
				167	10363.420	3215.959	10363.420	3215.959		
									10835.966	3175.506

SUBMARINE MINE CHARACTERISTIC LIST

MINE TYPE (II)	A	B	C	D	E	F	G	H	I	J	K	L
1	.0	.2	3	0	0	0	.8	.2	.6	.3	400	.9
2	.0	.2	3	0	0	0	.8	.2	.5	.3	450	.9
3	.1	.2	3	0	0	0	.8	.3	.4	.3	420	.9
4	.1	.2	3	0	0	0	.8	.2	.4	.3	380	.9
5	.0	.2	3	0	0	0	0	0	0	0	0	.9
6	.1	.2	3	0	0	0	0	0	0	0	0	.9
7	.1	.2	3	0	0	0	0	0	0	0	0	.9
8	.1	.3	2	0	.9	.9	0	0	0	0	0	.9

A = PROB OF DAMAGE ON HARDEST BOTTOM
B = PROB OF BURYING IN SOFTEST BOTTOM
C = INDICATOR OF MOOR OR BOTTOM TYPE
D = NWL TYPE IF BOTTOM MINE DOES NOT BURY/BURIES
E = PROB OF CASE/ANCHOR SEPARATION
F = PROB OF FULL ANCHOR CABLE DEPLOYMENT
G = PROB OF NORMAL RUN FOR A SELF-PROPELLED MINE
H = PROB OF MOTOR FAILURE,GIVEN FAILURE
I = PROB OF GYRO FAILURE,GIVEN FAILURE
J = PROB OF DEPTH FAILURE,GIVEN FAILURE
K = CEP FOR NORMAL RUN OF SELF-PROPELLED MINE
L = PROB MINE OPERATES,GIVEN IT HAS NOT BEEN DAMAGED (RELIABILITY)

MINE DESCRIPTION LIST

MINE CASE NO.	MINE TYPE II	MINE TYPE I	MINE CASE DEPTH	ARMING DELAY	STERILE TIME	SHIP COUNTS	TYPE OF MOOR
1	1	0	0	686	93	3	0
2	2	0	0	744	74	9	0
3	3	0	0	476	90	3	0
4	4	0	0	706	53	3	0
5	5	0	0	952	57	2	0
6	6	0	0	427	58	7	0
7	2	0	0	892	56	8	0
8	7	0	0	560	57	4	0
9	8	0	0	572	91	3	0
10	9	0	0	941	91	9	0
11	10	0	0	170	50	7	0
12	11	0	0	187	65	10	0
13	12	0	0	919	50	11	0
14	7	0	0	164	169	9	0
15	6	0	0	152	115	8	0
16	13	0	210	655	51	1	1
17	1	0	0	352	98	9	0
18	14	0	0	610	188	9	0
19	24	0	0	105	93	17	0
20	3	0	0	819	76	15	0
21	10	0	0	896	99	6	0
22	12	0	0	194	79	6	0
23	7	0	0	664	85	5	0
24	2	0	0	531	180	2	0
25	16	0	0	32	95	8	0
26	17	0	0	60	92	7	0
27	5	0	0	18	159	27	0
28	18	0	0	97	59	3	0
29	12	0	0	64	88	8	0
30	13	0	174	89	76	1	1
31	10	0	0	941	137	23	0
32	6	0	0	100	91	7	0
33	19	0	0	557	85	3	0
34	20	0	0	77	82	14	0
35	21	0	0	656	122	4	0
36	11	0	0	121	199	8	0
37	[illegible]	0	0	153	57	6	0
38	6	0	0	170	124	6	0
39	10	0	0	283	73	2	0
40	12	0	0	699	124	2	0
41	15	0	0	341	98	8	0
42	22	0	0	908	175	8	0
43	25	0	0	149	62	9	0
44	2[illegible]	0	0	246	94	7	0
45	[illegible]	0	0	366	99	10	0
46	[illegible]	0	0	415	138	2	0
47	12	0	0	7	97	18	0
48	3	0	0	574	55	5	0
49	14	0	0	312	67	9	0
50	15	0	0	373	158	9	0
51	23	0	0	884	52	3	0
52	8	0	0	114	65	7	0
53	2	0	0	893	196	8	0
54	2	0	0	831	75	9	0
55	10	0	0	961	94	16	0
56	1	0	0	232	65	6	0
57	17	0	0	885	57	9	0
58	19	0	0	834	97	3	0
59	9	0	0	13	125	20	0
60	6	0	0	301	140	7	0
61	7	0	0	903	78	9	0
62	12	0	0	263	88	5	0
63	10	0	0	24	170	4	0
64	3	0	140	135	20	1	1
65	7	0	22	180	19	1	1
66	10	0	2	193	999	1	1
67	[illegible]	0	40	893	88	1	2

68	4	0	60	983	420	1	2
69	10	0	2	173	999	1	1
70	10	0	2	89	999	1	1
71	5	0	138	388	76	1	1
72	7	0	63	180	69	1	1
73	9	0	0	490	96	1	0
74	8	0	219	362	47	1	1
75	5	0	120	191	339	1	1
76	1	0	220	765	71	1	1
77	9	0	0	173	41	1	0
78	7	0	26	180	16	1	1
79	6	0	235	271	50	1	1
80	5	0	220	379	280	1	1
81	8	0	226	996	38	1	1
82	1	0	224	358	48	1	1
83	2	0	225	265	72	1	1
84	7	0	53	180	120	1	1
85	9	0	0	366	98	1	0
86	5	0	235	458	24	1	1
87	6	0	240	780	77	1	1
88	8	0	232	514	34	1	1
89	5	0	190	198	37	1	1
90	1	0	100	919	83	1	1
91	9	0	0	189	345	1	0
92	7	0	31	180	284	1	1
93	1	0	222	373	81	1	1
94	6	0	220	622	74	1	1
95	5	0	180	122	241	1	1
96	6	0	246	221	43	1	1
97	9	0	0	130	44	1	0
98	1	0	240	366	70	1	1
99	7	0	42	180	308	1	1
100	5	0	218	104	274	1	1
101	8	0	220	231	83	1	1
102	6	0	204	922	73	1	1
103	8	0	230	910	60	1	1
104	9	0	0	159	318	1	0
105	1	0	245	704	80	1	1
106	5	0	250	178	249	1	1
107	9	0	0	357	40	1	0
108	7	0	58	180	97	1	1
109	5	0	235	143	65	1	1
110	8	0	225	211	88	1	1
111	7	0	29	180	69	1	1
112	9	0	0	579	300	1	0
113	1	0	196	654	83	1	1
114	1	0	234	543	42	1	1
115	6	0	230	257	86	1	1
116	2	0	238	206	40	1	1
117	7	0	30	180	143	1	1
118	8	0	249	440	67	1	1
119	9	0	0	190	49	1	0
120	6	0	250	625	70	1	1
121	2	0	260	4	75	1	1
122	8	0	240	243	42	1	1
123	1	0	250	892	95	1	1
124	9	0	0	207	67	1	0
125	7	0	27	180	158	1	1
126	6	0	233	251	74	1	1
127	2	0	240	294	44	1	1
128	8	0	242	235	89	1	1
129	9	0	0	357	178	1	0
130	7	0	51	180	117	1	1
131	8	0	269	308	83	1	1
132	2	0	272	257	65	1	1
133	9	0	0	629	142	1	1
134	1	0	260	278	60	1	1
135	2	0	249	323	50	1	1
136	6	0	252	941	42	1	1
137	9	0	0	409	61	1	0
138	7	0	47	180	17	1	1
139	2	0	275	648	16	1	1
140	9	0	0	467	198	1	0
141	6	0	270	717	95	1	1
142	1	0	270	322	49	1	1
143	2	0	269	718	99	1	1
144	8	0	256	701	64	1	1
145	9	0	0	123	74	1	0
146	7	0	35	180	99	1	1
147	1	0	215	986	30	1	1
148	2	0	117	884	28	1	1
149	1	0	0	180	111	7	0
150	3	0	0	531	218	5	0
151	1	0	0	180	303	1	0
152	2	0	0	573	85	1	0
153	3	0	0	161	317	2	0
154	4	0	0	383	101	1	0
155	5	0	0	449	51	7	0

156	6	0	0	603	119	4	0
157	7	0	0	551	104	1	0
158	5	0	0	848	13	3	0
159	[illegible]	0	180	180	21	1	1
160	[illegible]	0	0	760	38	1	0
161	[illegible]	0	0	180	66	4	0
162	4	0	0	961	119	1	0
163	[illegible]	0	0	136	303	2	0
164	[illegible]	0	0	992	115	1	0
165	8	0	150	180	78	1	1
166	6	0	0	692	54	7	0
167	8	0	180	180	83	1	1

RUN NO. 26 IR FOR THIS RUN IS 54880769

DETAILED NARRATIVE

MINE NO.	TIME LAYED	TIME ACTIVE	XCOORD (YDS)	YCOORD (YDS)	CASE DEPTH (FT)	REMARKS
149	160842.5	161142.5	9181.873	842.700	210.19	
151	160851.6	161151.6	8536.183	516.263	192.11	
152	160901.5	161834.5	9629.014	6141.716	231.78	MOTOR FAILURE.
153	160912.6	161153.6	10784.901	1596.934	148.86	
154	160922.6	161545.6	10537.421	2340.911	173.74	BURIED.
155	161000.8	161729.8	10121.841	2861.498	192.95	
156	161004.0	162307.0	9603.965	2549.883	202.41	
157	161006.2	161917.2	9328.564	2446.330	204.42	
158	161009.1	170017.1	8950.209	2138.655	203.17	
159	161011.8	161711.8	8554.963	1992.331	29.17	
160	180942.3	182222.3	8190.420	7053.138	259.47	GYRO FAILURE.
161	180945.4	0	8222.215	2603.207	222.83	UNRELIABLE.
162	180948.5	190149.5	7817.592	1898.838	225.63	BURIED.
163	180951.1	0	8808.523	8081.707	280.41	UNRELIABLE. DEPTH FAILURE.
164	180953.8	190225.8	8255.621	3660.337	239.70	
165	200305.7	200605.7	9402.527	3328.325	221.27	CASE/ANCHOR SEPARATION FAILURE.
166	200308.2	201440.2	9889.044	3135.396	204.64	
167	200311.9	200611.9	10422.000	3161.787	6.45	

64	200731.5	200946.5	2116.989	1191.531	2.42	
65	200732.6	0	2456.748	1429.807	129.61	CASE/ANCHOR SEPARATION FAILURE. DID NOT ARM DUE TO CASE/ANCHOR SEPARATION FAILURE.
66	200733.6	201046.6	2875.653	1367.859	2.00	
67	200734.7	202227.7	3246.959	1522.943	23.79	
68	200735.7	202358.7	3718.484	1723.527	6.79	
69	200736.6	0	3992.162	1871.736	2.00	UNRELIABLE.
70	200737.6	200906.6	4450.007	2012.575	2.00	
71	200738.7	201406.7	4782.413	2132.115	3.36	
72	200739.6	201039.6	5132.311	2261.826	63.00	
73	200740.6	201550.6	5673.306	2483.894	206.29	
74	200741.9	201343.9	5993.114	2580.777	6.03	
75	200743.0	0	6484.532	2620.931	117.97	UNRELIABLE.
76	200743.9	202028.9	6875.743	2758.968	22.29	
77	200745.0	201038.0	7266.030	2917.910	239.42	
78	200746.0	201046.0	7557.700	3124.600	26.00	
79	200748.7	201219.7	7799.604	4243.575	15.12	
80	200750.8	201409.8	8452.826	3326.587	13.63	
81	200751.8	210027.8	8721.343	3647.703	9.35	
82	200752.9	201350.9	9140.330	3744.086	6.07	
83	200753.8	0	9581.667	3817.024	-3.11	UNRELIABLE. MINE IS WATCHING.
84	200754.8	201054.8	9910.805	4114.849	53.00	
85	200759.3	201405.3	9155.847	4077.197	233.13	
86	200801.9	201539.9	7895.026	3724.821	8.67	
87	200804.6	202104.6	6772.888	3334.730	12.52	
88	200807.2	201641.2	5945.818	3210.943	21.02	
89	200810.1	201128.1	4712.299	2528.054	-5.20	MINE IS WATCHING.
90	200812.6	202331.6	3924.121	2333.678	63.63	
91	200815.5	201124.5	2900.956	1935.698	153.74	

92	200918.2	201118.2	1938.071	1569.185	31.00	
114	200902.6	201205.6	1946.301	2913.729	9.75	
115	200905.1	201322.1	2606.530	3035.436	9.11	
116	200907.8	201233.8	3259.853	3273.013	11.72	
117	200910.3	201210.3	3945.181	3645.174	30.00	
118	200912.8	0	4572.645	3772.342	14.89	UNRELIABLE.
119	200915.4	201225.4	5155.193	4030.930	273.33	
120	200917.9	201942.9	5502.364	4259.555	23.59	
121	200920.3	200924.3	6411.336	4417.174	8.35	
122	200923.1	201326.1	7212.071	4770.683	258.25	CASE/ANCHOR SEPARATION FAILURE.
123	200925.5	210017.5	7730.326	4896.739	.63	
124	200928.2	201255.2	8479.093	5221.977	246.55	
125	200930.6	201230.6	9066.419	5369.687	27.00	
126	200933.1	201344.1	9657.238	5606.988	6.74	
124	200939.4	201306.4	9607.625	5960.664	231.42	
128	200943.0	201338.0	8606.141	5557.597	6.13	
129	200946.8	201543.8	7670.262	5208.291	251.45	
130	200950.1	201250.1	6764.716	5286.796	51.00	
131	200954.0	201502.0	5874.930	4808.977	9.67	
132	200957.7	201414.7	4985.611	4254.983	222.88	MOORING CABLE DID NOT DEPLOY FULLY.
133	201000.9	202029.9	4209.052	3942.021	268.37	
134	201004.4	201442.4	3374.565	3682.795	3.23	
135	201007.8	201530.8	2329.999	3186.565	.68	
136	201009.9	210150.9	1941.995	3239.885	10.32	
137	201012.1	201708.1	2356.277	3751.441	278.77	
138	201021.8	201321.8	2958.315	3938.363	47.00	
139	201024.8	202112.8	3945.284	4390.028	5.26	
140	201027.9	201914.9	4615.193	4699.795	284.41	

141	201030.6	202[illegible]27.6	3228.774	4711.980	12.40	
142	201033.7	201555.7	5956.897	5098.730	9.96	
143	201036.9	202234.9	6822.195	5541.840	-1.61	MINE IS WATCHING.
144	201039.7	202220.7	7478.044	5950.378	6.37	
145	201042.9	201245.9	8797.360	5997.983	254.70	
146	201045.9	201745.9	9128.243	6295.151	35.00	
147	201049.2	210315.2	9987.343	6779.087	236.76	CASE/ANCHOR SEPARATION FAILURE.
148	201050.5	210134.5	10159.381	6860.516	116.52	
1	221551.4	230319.4	15536.824	6768.967	23.11	BURIED.
2	221551.5	0	15060.841	6814.374	65.19	UNRELIABLE.
3	221551.6	0	14414.617	6958.430	96.97	DAMAGED ON WATER IMPACT. BURIED.
4	221551.7	230337.7	13847.602	6679.772	116.00	
5	221551.8	230743.8	12593.103	6952.005	185.82	
6	221551.9	222258.9	12113.634	6685.494	185.59	BURIED.
7	221552.0	230644.0	11611.142	6694.755	198.59	
8	221552.1	0	10373.213	6806.202	228.29	CHUTE DID NOT DEPLOY. UNRELIABLE.
9	221555.0	230127.0	15387.834	6224.617	22.16	
10	221555.1	230736.1	14415.165	6745.271	93.22	
11	221555.2	221845.2	13900.311	6273.018	107.04	
12	221555.3	221902.3	13461.016	6261.597	124.99	
13	221555.4	230714.4	12962.702	6530.729	152.37	
14	221555.5	0	11931.900	6617.400	188.84	DAMAGED ON WATER IMPACT.
15	221555.6	221827.6	10943.128	6366.968	210.19	
16	221555.7	230250.7	10661.162	6031.830	.08	
17	221558.7	222150.7	15473.408	5830.422	9.20	
18	221558.8	230208.8	14436.423	6142.096	81.08	
19	221558.9	221743.9	14115.580	6196.850	96.41	CHUTE DID NOT DEPLOY.

20	221559.0	0	13229.004	6152.622	131.43	DAMAGED ON WATER IMPACT.
21	221559.1	230651.1	12476.053	6163.049	162.60	
22	221559.2	0	11753.381	6067.707	186.87	UNRELIABLE.
23	221559.3	230302.3	10937.212	5903.713	202.83	
24	221559.7	0	9017.098	6058.565	243.78	BURIED. UNRELIABLE.
35	221608.4	230304.4	13481.056	5097.687	99.90	BURIED.
36	221608.5	221809.5	12989.948	5359.647	126.33	CHUTE DID NOT DEPLOY. BURIED.
41	221612.8	222153.8	14851.949	4760.103	43.78	
43	221613.0	221842.0	13165.639	4684.565	109.12	CHUTE DID NOT DEPLOY. BURIED.
44	221613.1	222019.1	12954.295	4709.936	118.04	BURIED.
45	221613.2	222219.2	12122.245	4820.531	153.92	BURIED.
47	221613.4	221620.4	10594.176	4736.803	204.08	
49	221613.0	222125.0	13035.384	4055.517	102.34	
50	221613.1	222226.1	14337.459	5051.678	72.57	
53	221613.3	230706.3	11209.538	5148.967	187.76	BURIED.
54	221613.4	230604.4	9896.506	4319.897	220.70	BURIED.
55	221613.5	230914.5	9813.542	6111.675	227.76	
56	221618.1	0	15313.326	3741.904	-46.35	ON THE BEACH.
59	221613.3	221631.3	13143.522	2859.811	78.23	
60	221618.4	222119.4	13953.263	3306.346	51.99	
61	221618.5	230721.5	11084.574	5716.013	197.32	CHUTE DID NOT DEPLOY. BURIED.
62	221618.6	222041.6	10088.326	3988.960	212.11	BURIED.

MINES LAYED 123 MINES EFFECTIVE 106 MINES BURIED 15 MINES NOT BURIED 0 MINES COMPROMISED 4

SUMMARY OF RESULTS

RUN NO.	MINES LAYED	MINES EFFECTIVE	MINES BURIED	MINES NOT BURIED	MINES COMPROMISED
1	147	[illegible]	24	0	8
2	[illegible]	[illegible]	25	0	4
3	119	98	22	0	4
4	126	103	26	0	7
5	119	95	18	0	6
6	156	129	20	0	7
7	110	99	19	0	5
8	110	89	22	0	6
9	157	133	26	0	5
10	144	120	20	0	6
11	135	108	20	0	7
12	126	107	18	0	6
13	139	115	22	0	9
14	132	110	21	0	6
15	147	119	21	0	9
16	135	106	24	0	6
17	136	115	18	0	5
18	157	137	21	0	5
19	101	75	24	0	6
20	104	88	21	0	4
21	162	136	27	0	7
22	95	73	20	0	7
23	128	111	19	0	5
24	133	113	23	0	6
25	115	91	18	0	8
26	123	106	15	0	4
27	147	120	17	0	8
28	159	131	30	0	6
29	150	120	17	0	9
30	134	108	24	0	6
31	128	109	21	0	5
32	123	97	25	0	8
33	148	127	25	0	8
34	136	117	16	0	5
35	157	129	27	0	8
36	157	131	22	0	6
37	160	129	20	0	7
38	151	123	22	0	5
39	153	124	19	0	9
40	112	91	16	0	5
41	154	126	22	0	6
42	150	113	15	0	10
43	158	132	22	0	7
44	121	106	21	0	3
45	139	120	23	0	2
46	[illegible]	133	24	0	7
47	153	110	25	0	5
48	[illegible]	114	20	0	11
49	[illegible]	128	22	0	8
50	127	114	15	0	6
51	[illegible]	102	23	0	8
[illegible]	[illegible]	114	17	0	7
[illegible]	[illegible]	116	23	0	5
54	[illegible]	[illegible]	24	0	7
[illegible]	[illegible]	113	25	0	6
[illegible]	[illegible]	138	21	0	4
[illegible]	146	123	18	0	7
[illegible]	[illegible]	109	20	0	5
59	[illegible]	107	19	0	5
60	[illegible]	123	15	0	11
61	[illegible]	124	18	0	10
[illegible]	141	[illegible]	18	0	7
[illegible]	116	99	16	0	2
[illegible]	[illegible]	101	13	0	3
65	[illegible]	129	15	0	[illegible]
66	[illegible]	142	23	0	5
[illegible]	[illegible]	[illegible]	24	0	6

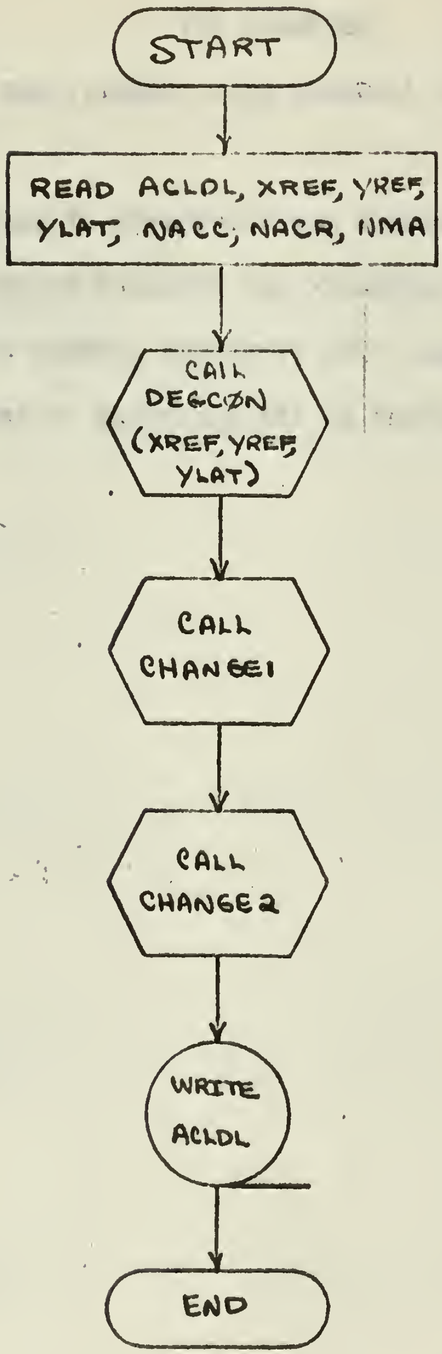
68	154	129	22	0	5
69	152	128	22	0	8
70	157	129	19	0	7
71	142	119	20	0	7
72	132	107	15	0	7
73	146	121	23	0	7
74	125	107	13	0	5
75	156	121	26	0	10
76	143	119	22	0	8
77	84	65	22	0	4
78	152	128	20	0	7
79	125	104	20	0	3
80	143	118	19	0	8
AVERAGE	137	114	20	0	6

APPENDIX XIV

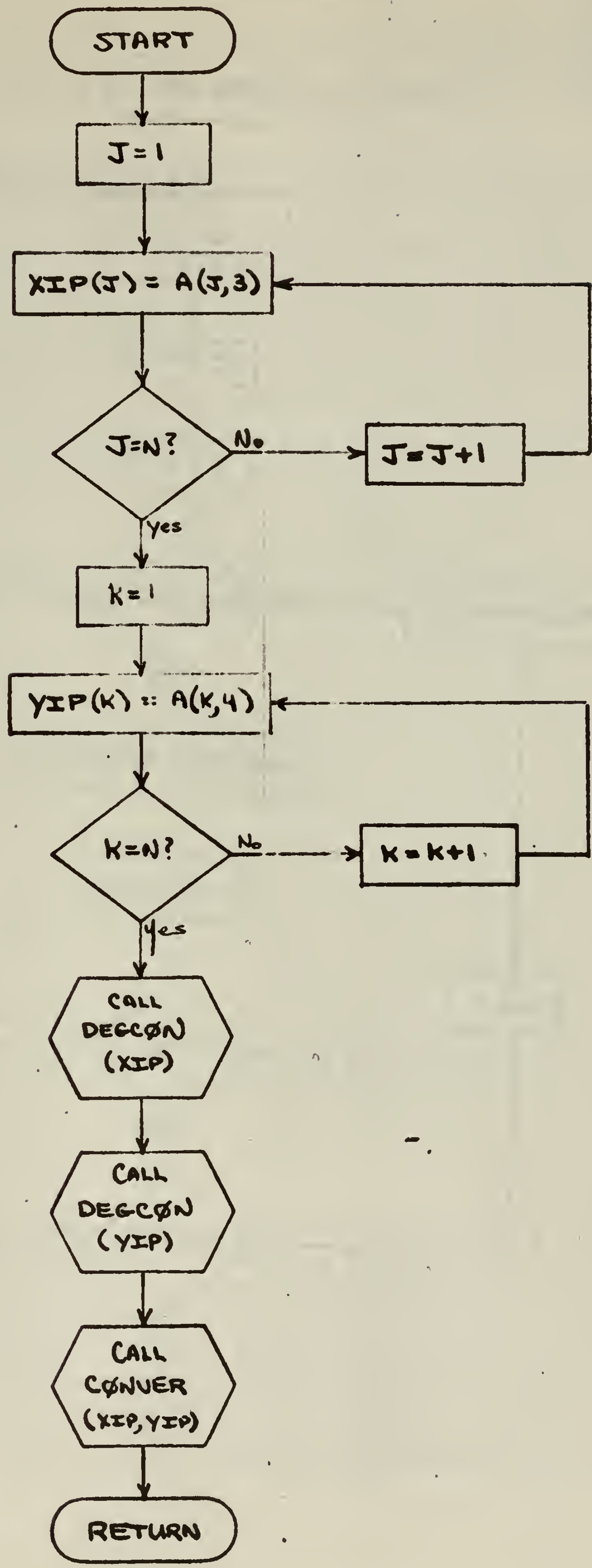
FLOWCHARTS FOR PROGRAMS GRID, SURFIT, AND MINDEL1

This appendix contains the flowcharts of programs GRID, SURFIT, and MINDEL1. These flowcharts are included to aid the user in working with those programs. The flowchart symbols shown in Figure 18 and the approach described at the beginning of Appendix IV were used.

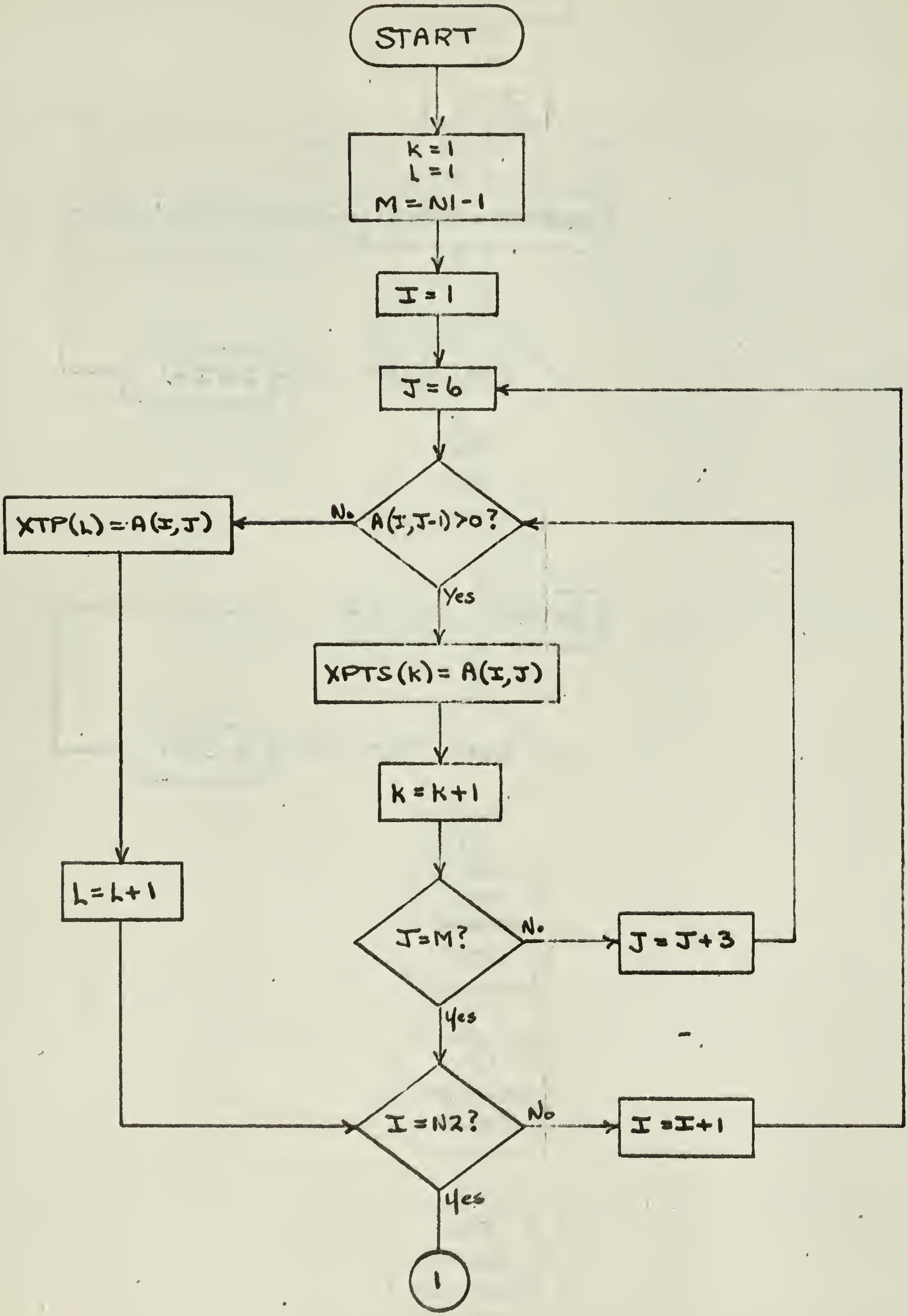
PRØGRAM GRID

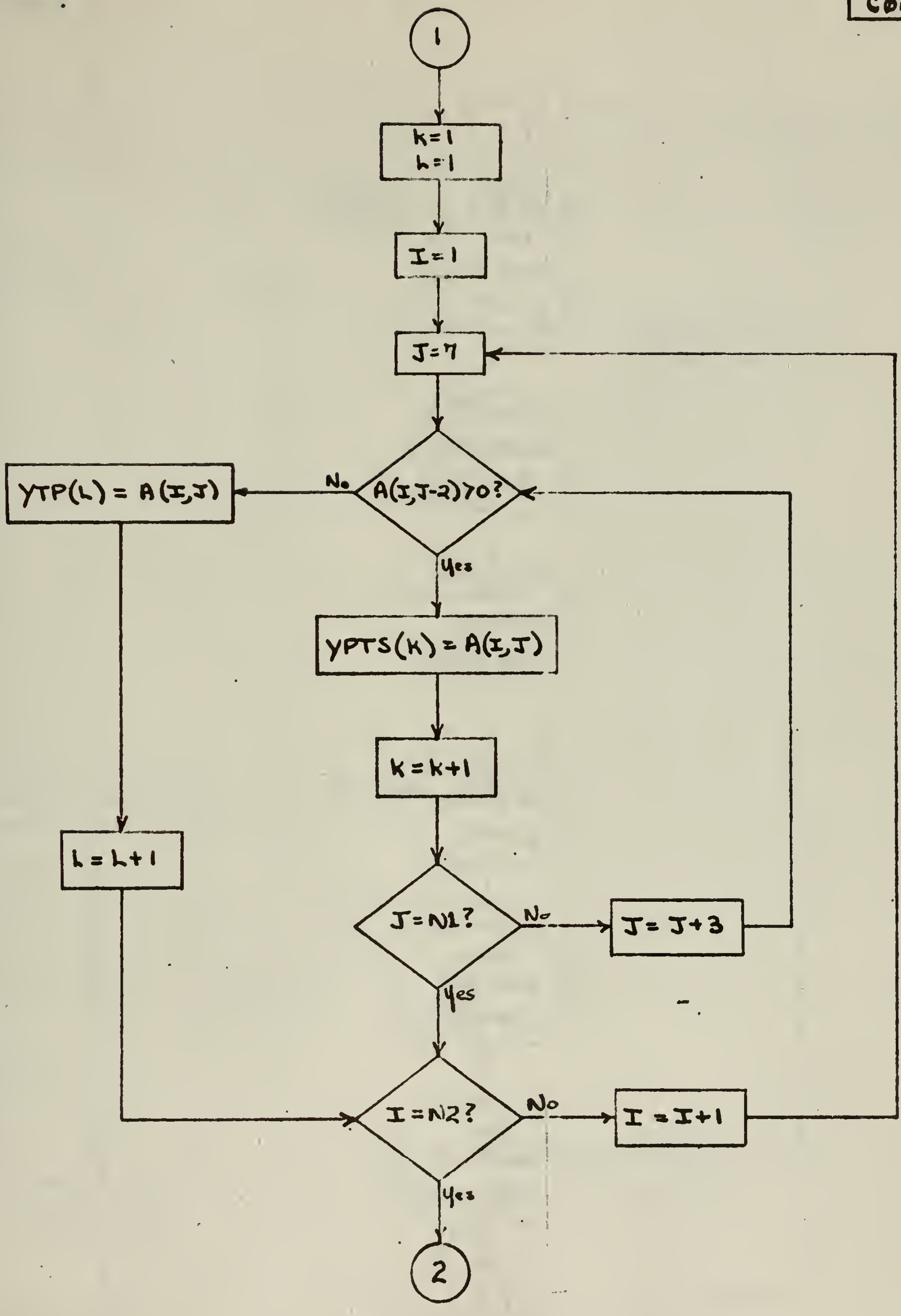


SUBRØUTINE CHANGE1 .

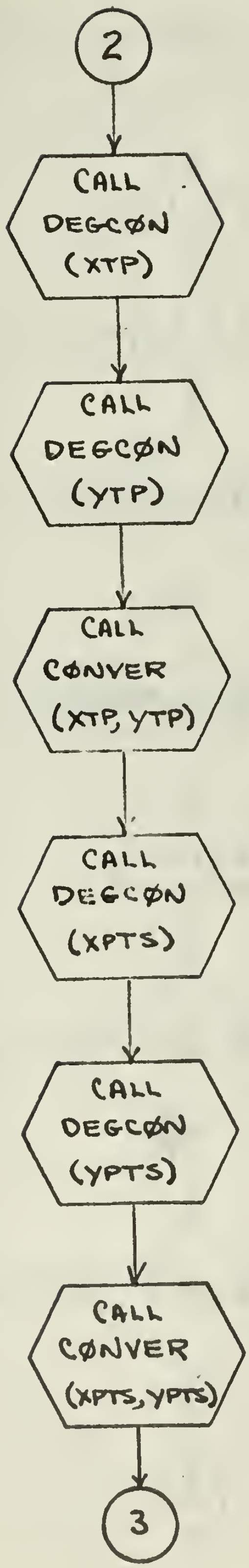


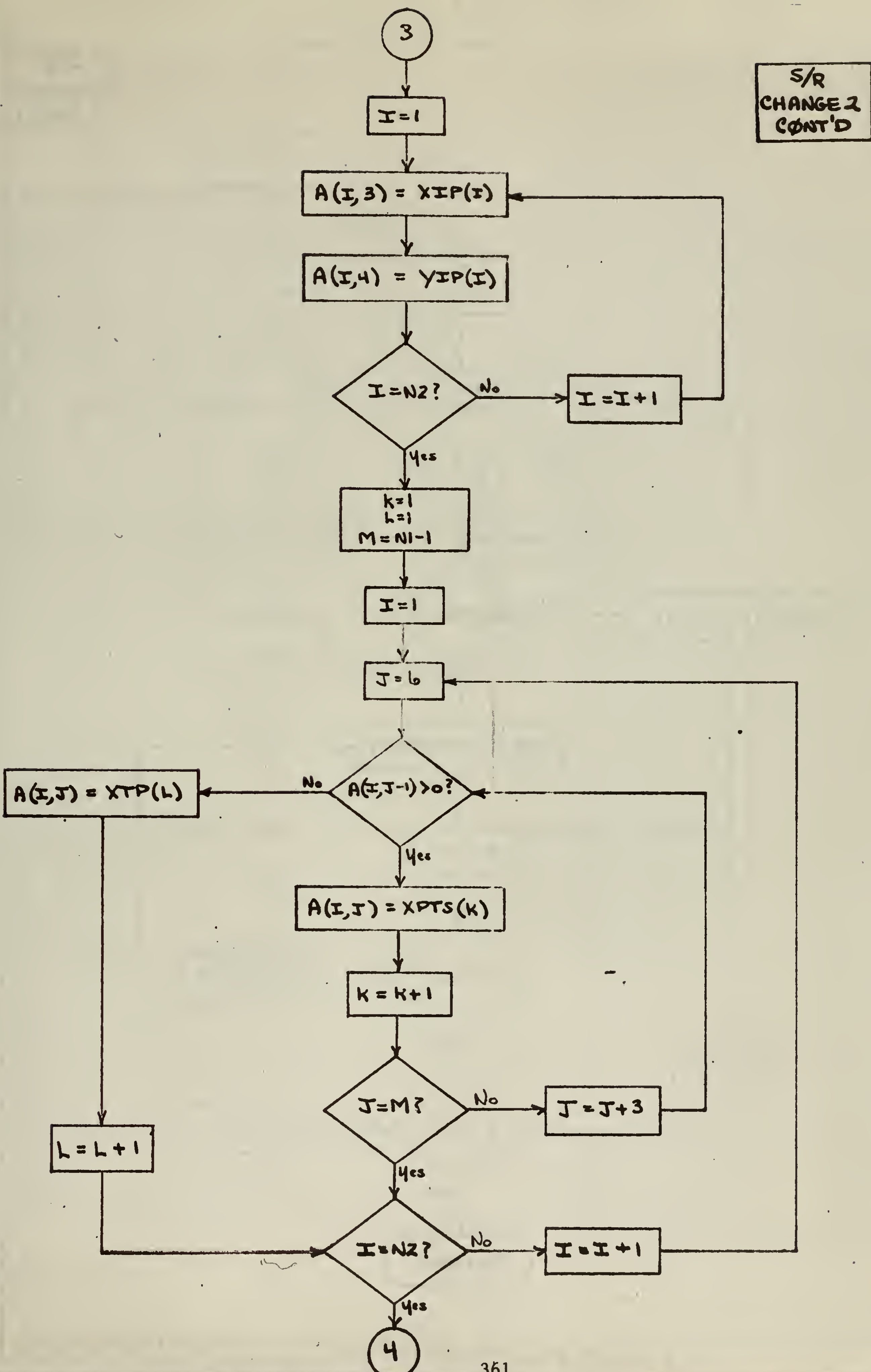
SUBRØUTINE CHANGE: 2



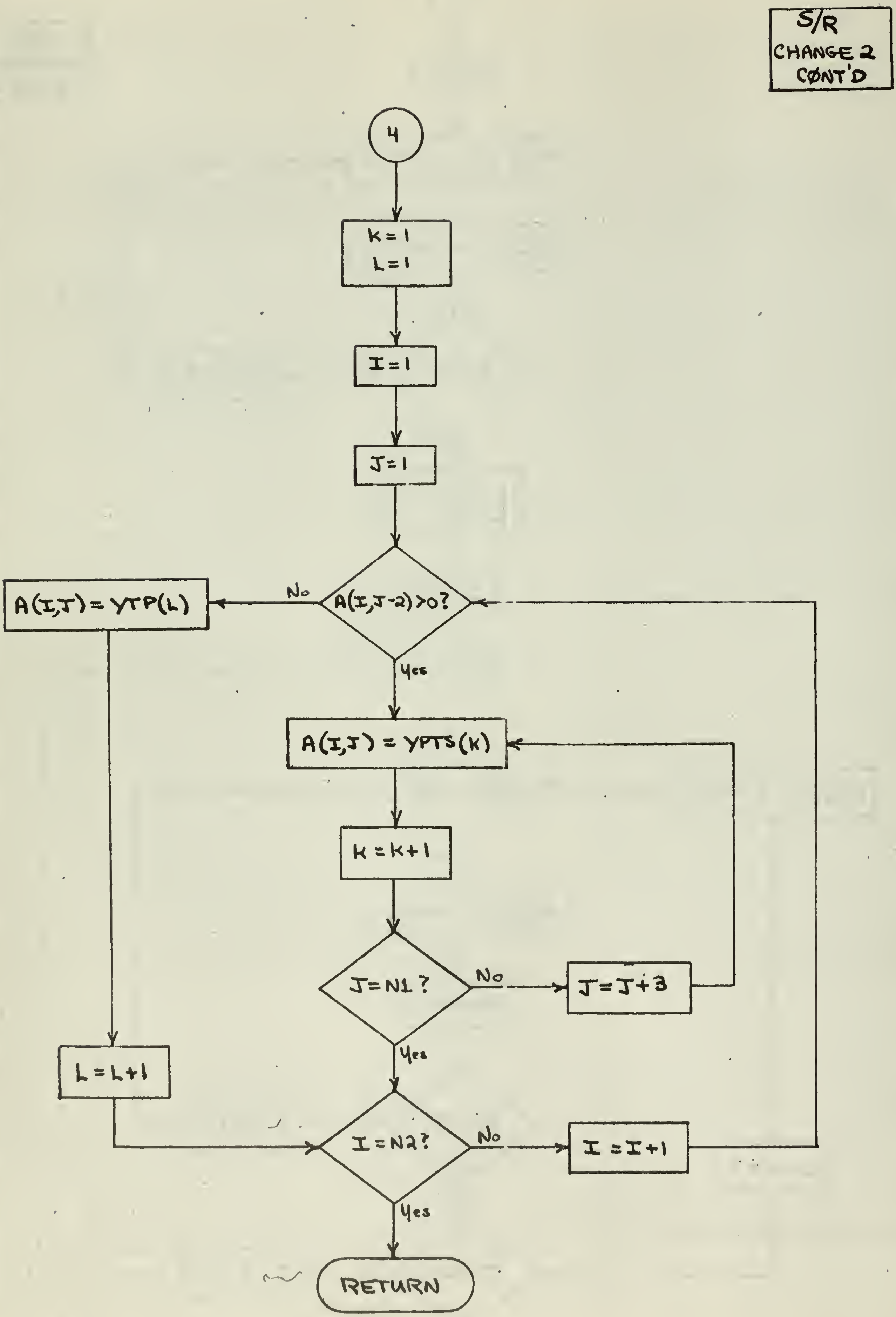

1
k=1
L=1
I=1
J=7
A(I,J-2)>0?
No
YTP(L) = A(I,J)
Yes
YPTS(K) = A(I,J)
K=K+1
L=L+1
J=N1?
No
J= J+3
Yes
I=N2?
No
I =I+1
Yes
2

S/R
CHANGE 2
CØNT'D

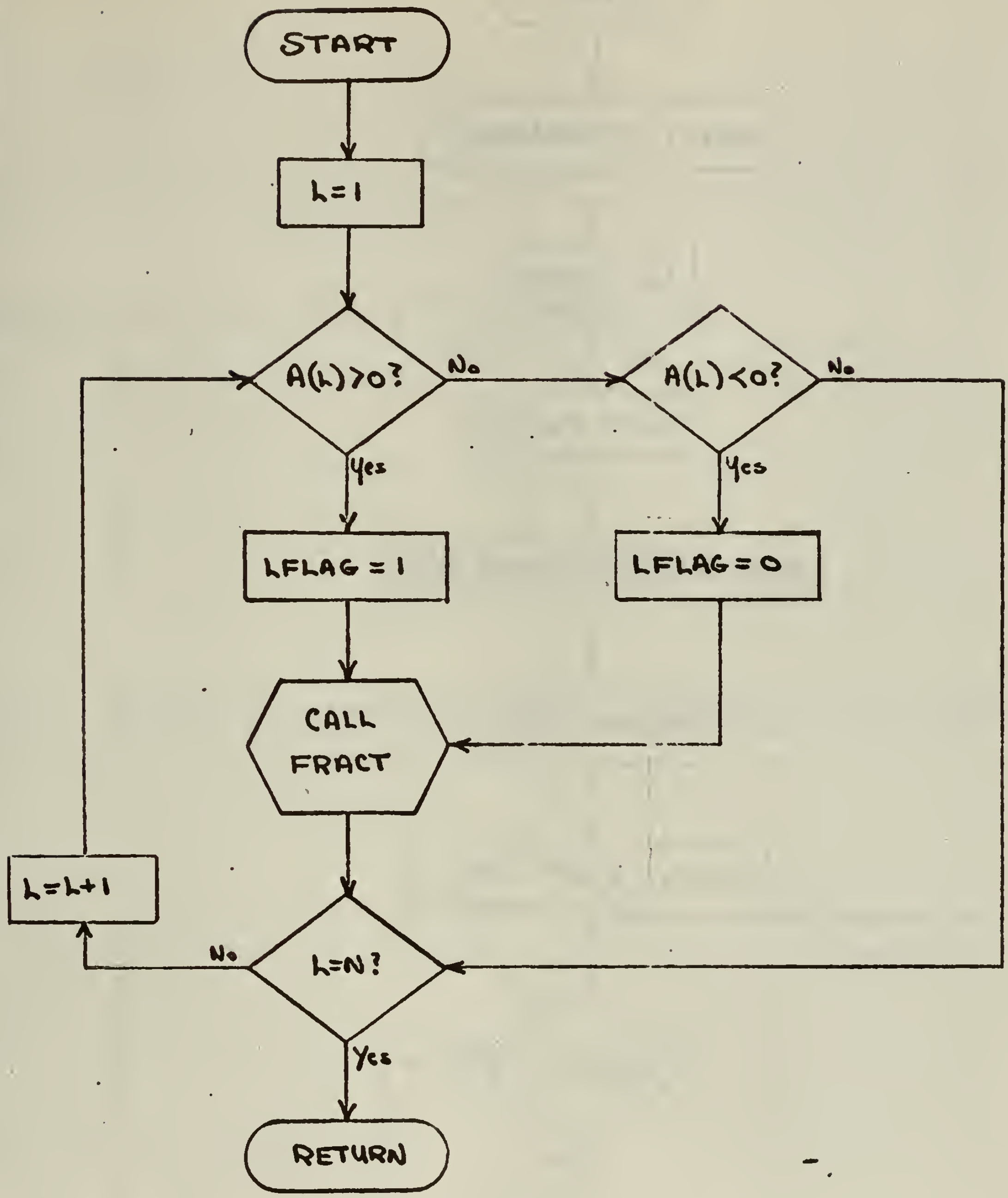




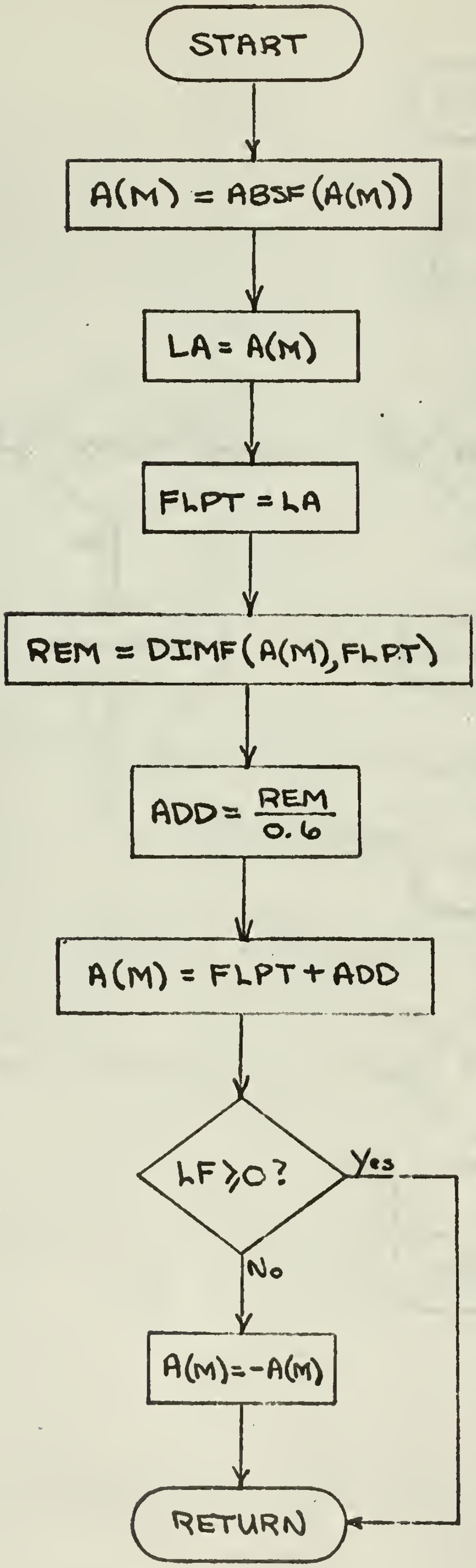
S/R
CHANGE 2
CØNT'D
3
I=1
A(I,3) = XIP(I)
A(I,4) = YIP(I)
I=N2?
No
I=I+1
yes
K=1
L=1
M=N1-1
I=1
J=6
A(I,J-1)>0?
No
A(I,J) = XTP(L)
yes
A(I,J) = XPTS(K)
K=K+1
J=M?
No
J=J+3
L=L+1
yes
I=N2?
No
I=I+1
yes
4


S/R
CHANGE 2
CØNT'D
4
K=1
L=1
I=1
J=1
A(I,J-2)>0?
No
A(I,J)=YTP(L)
Yes
A(I,J) = YPTS(K)
K=K+1
J=N1?
No
J=J+3
Yes
L=L+1
I=N2?
No
I=I+1
Yes
RETURN

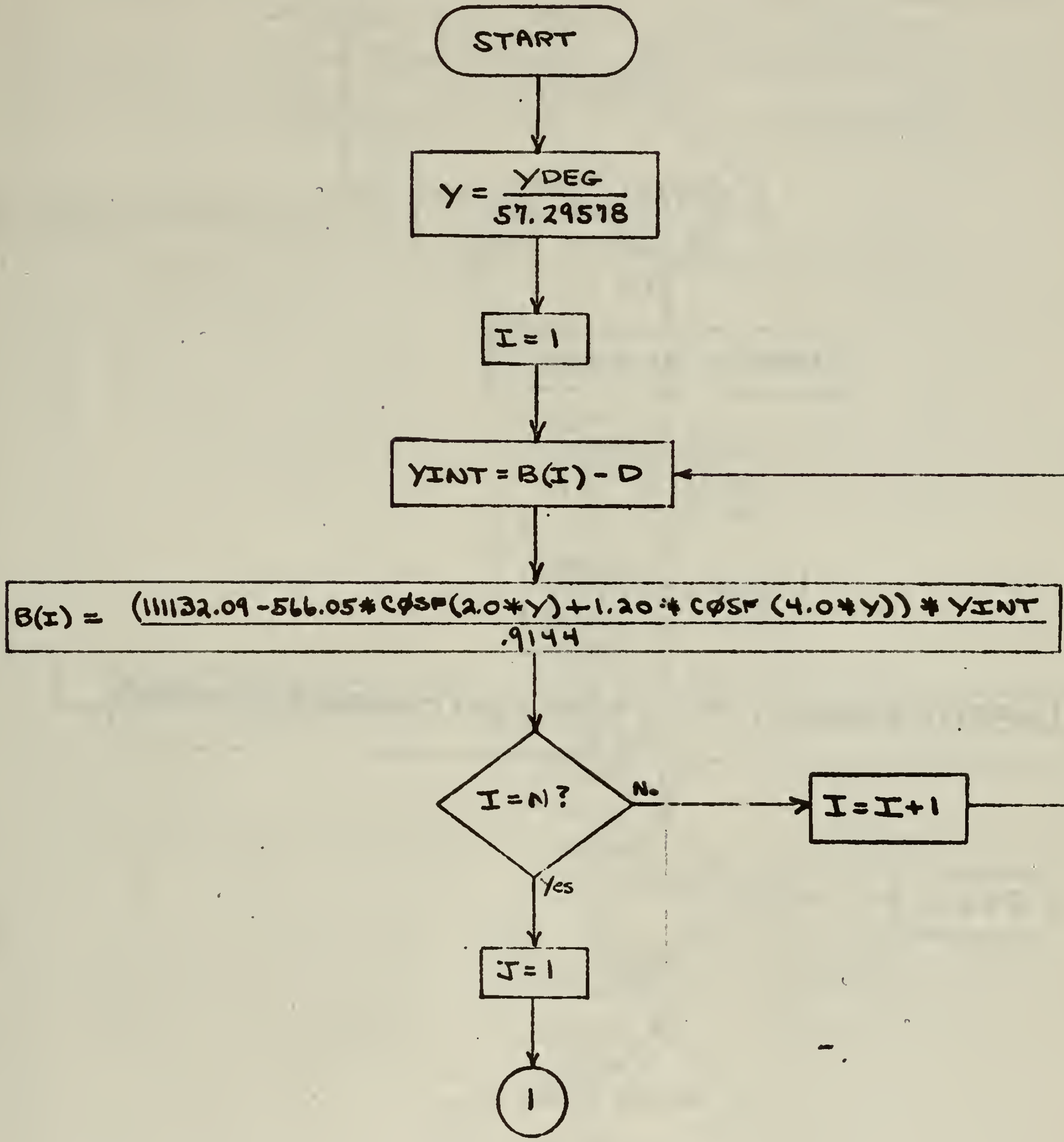
SUBRØUTINE DEGCØN

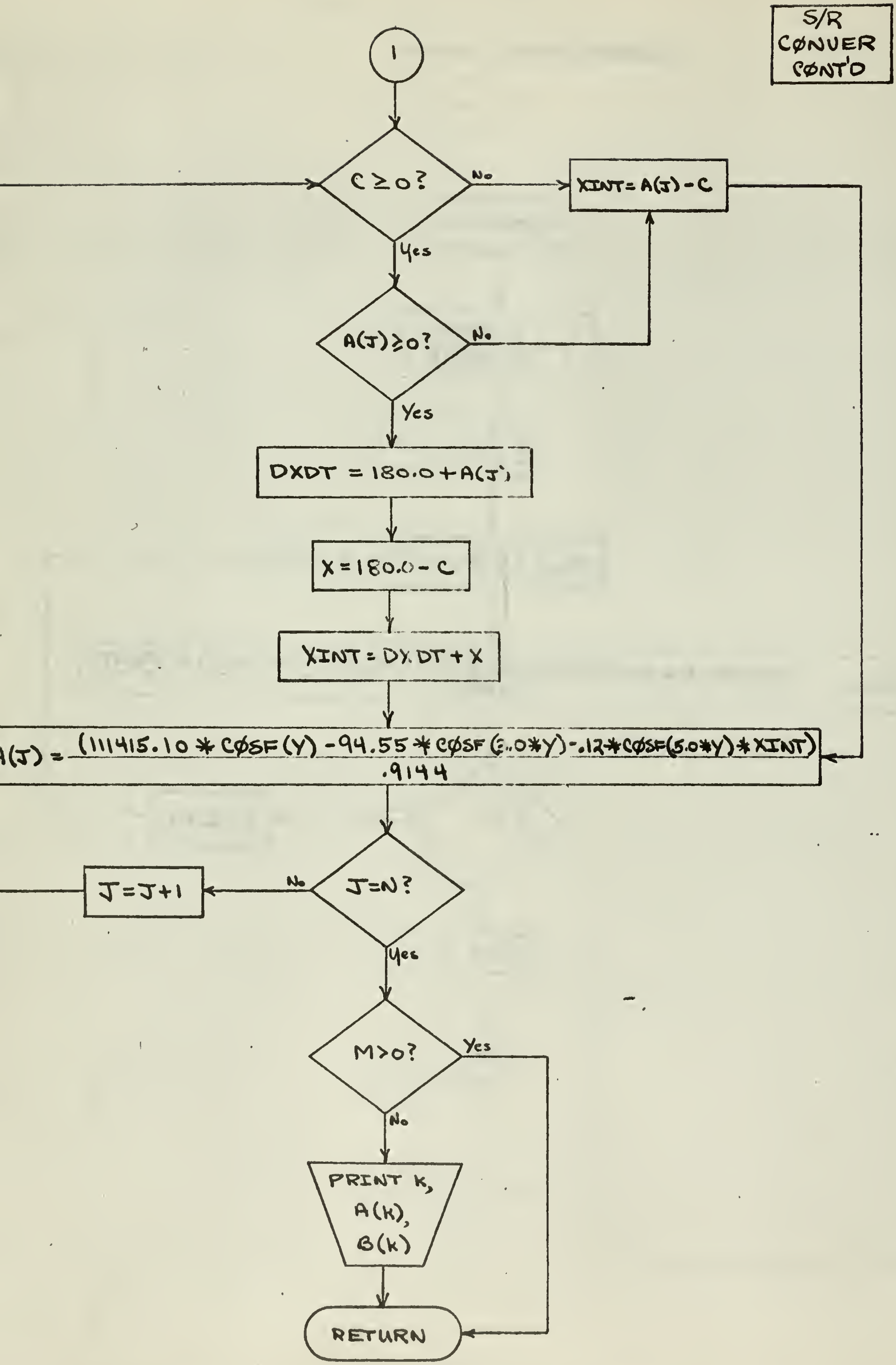


SUBRØUTINE FRACT

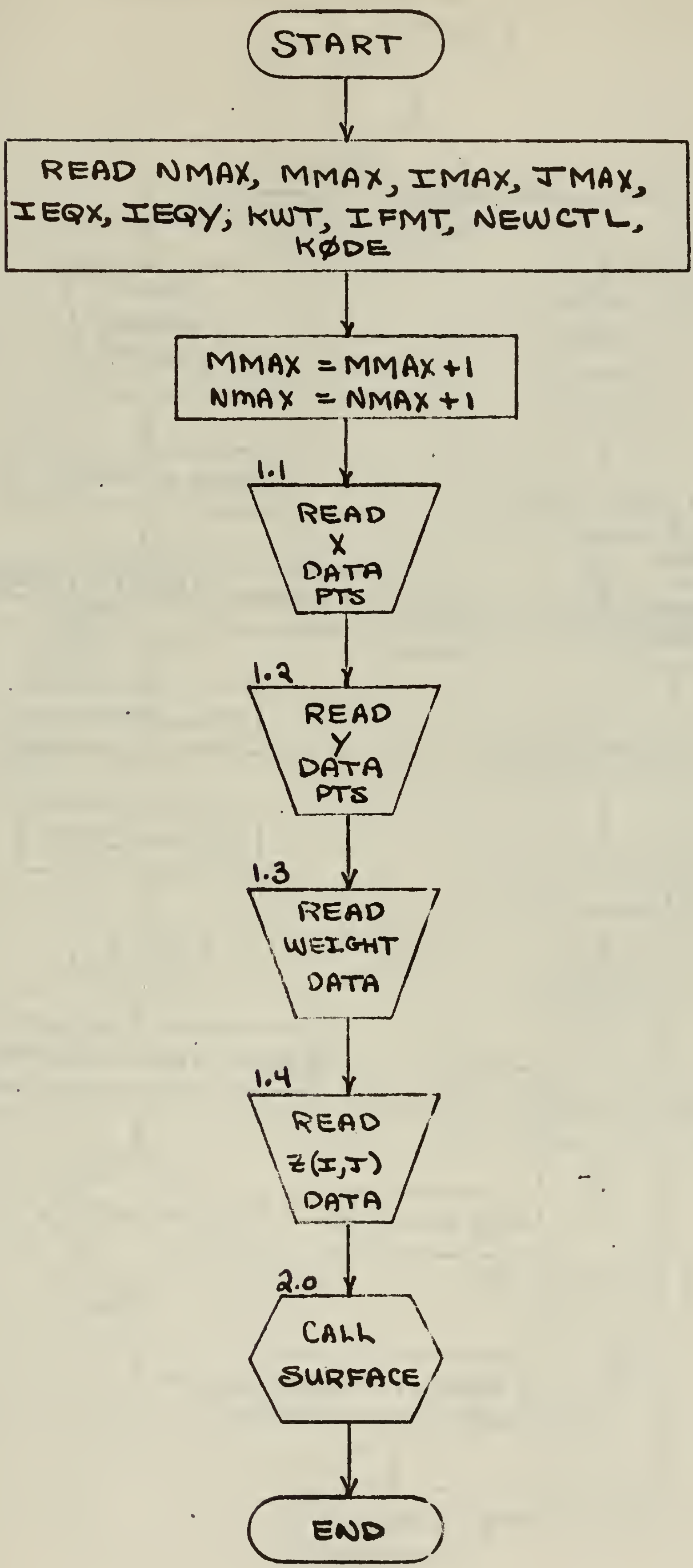


SUBRØUTINE CØNVER:

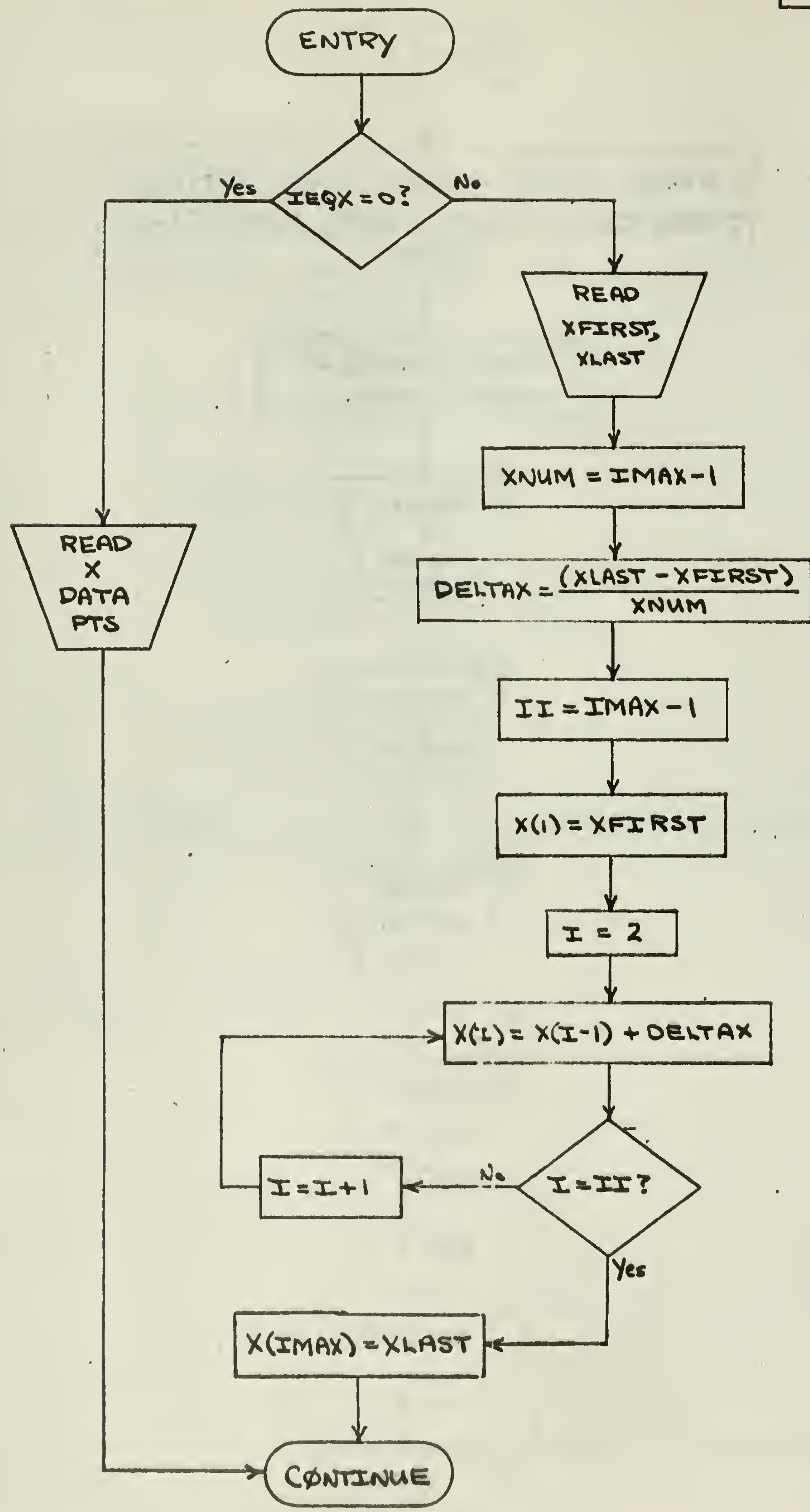



S/R CØNVER CØNT'D
1
C ≥ 0?
No
Yes
XINT = A(J) - C
A(J) ≥ 0?
No
Yes
DXDT = 180.0 + A(J)
X = 180.0 - C
XINT = DXDT + X
A(J) = (111415.10 * CØSF(Y) - 94.55 * CØSF(3.0*Y) - .12 * CØSF(5.0*Y) * XINT) / .9144
J = N?
No
J = J + 1
Yes
M > 0?
Yes
No
PRINT K, A(K), B(K)
RETURN

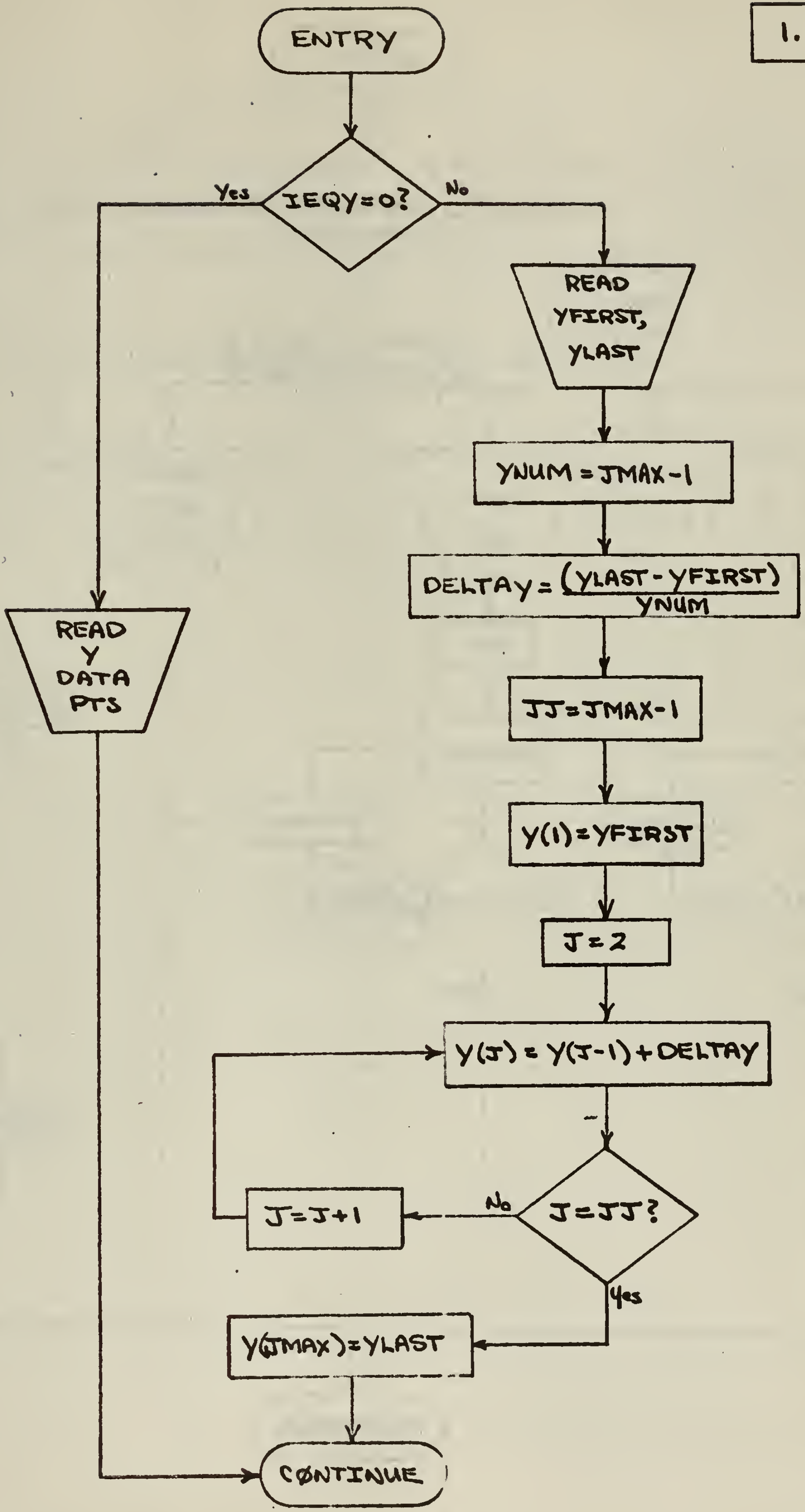
PRØGRAM SURFIT

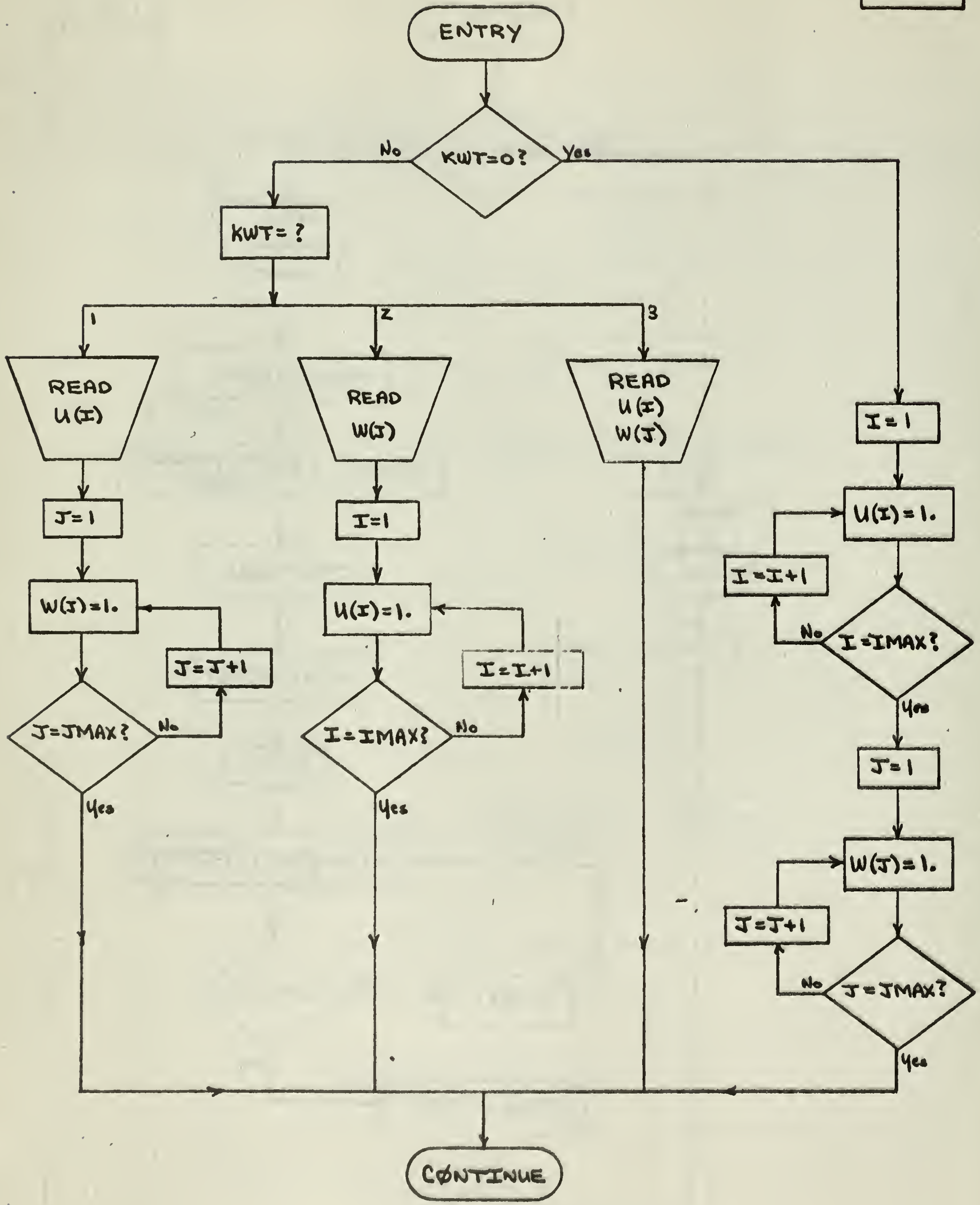


1.1

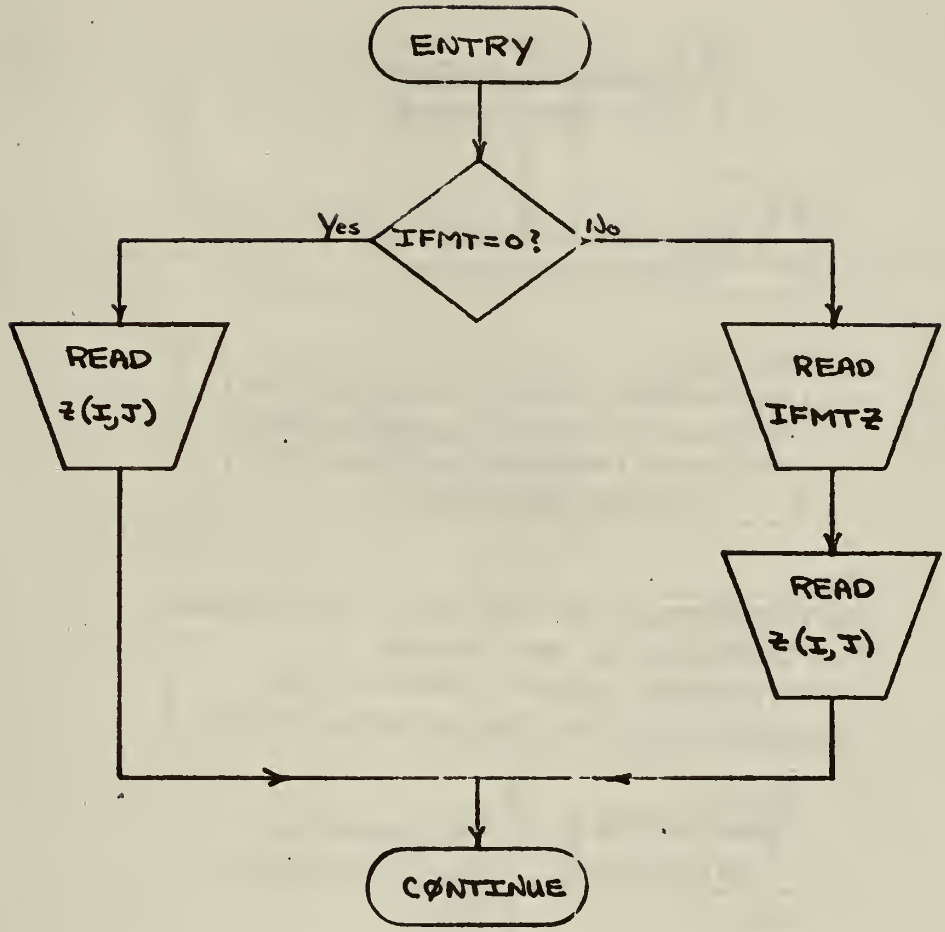

ENTRY
IEQX = 0?
Yes
No
READ X DATA PTS
READ XFIRST, XLAST
XNUM = IMAX-1
DELTAX = (XLAST - XFIRST) / XNUM
II = IMAX - 1
X(1) = XFIRST
I = 2
X(I) = X(I-1) + DELTAX
I = II?
No
I = I+1
Yes
X(IMAX) = XLAST
CØNTINUE

1.2


ENTRY
IEQY=0?
Yes
No
READ YFIRST, YLAST
YNUM = JMAX-1
DELTAY = (YLAST - YFIRST) / YNUM
JJ=JMAX-1
Y(1)=YFIRST
J=2
Y(J) = Y(J-1) + DELTAY
J=JJ?
No
J=J+1
Yes
Y(JMAX)=YLAST
READ Y DATA PTS
CØNTINUE

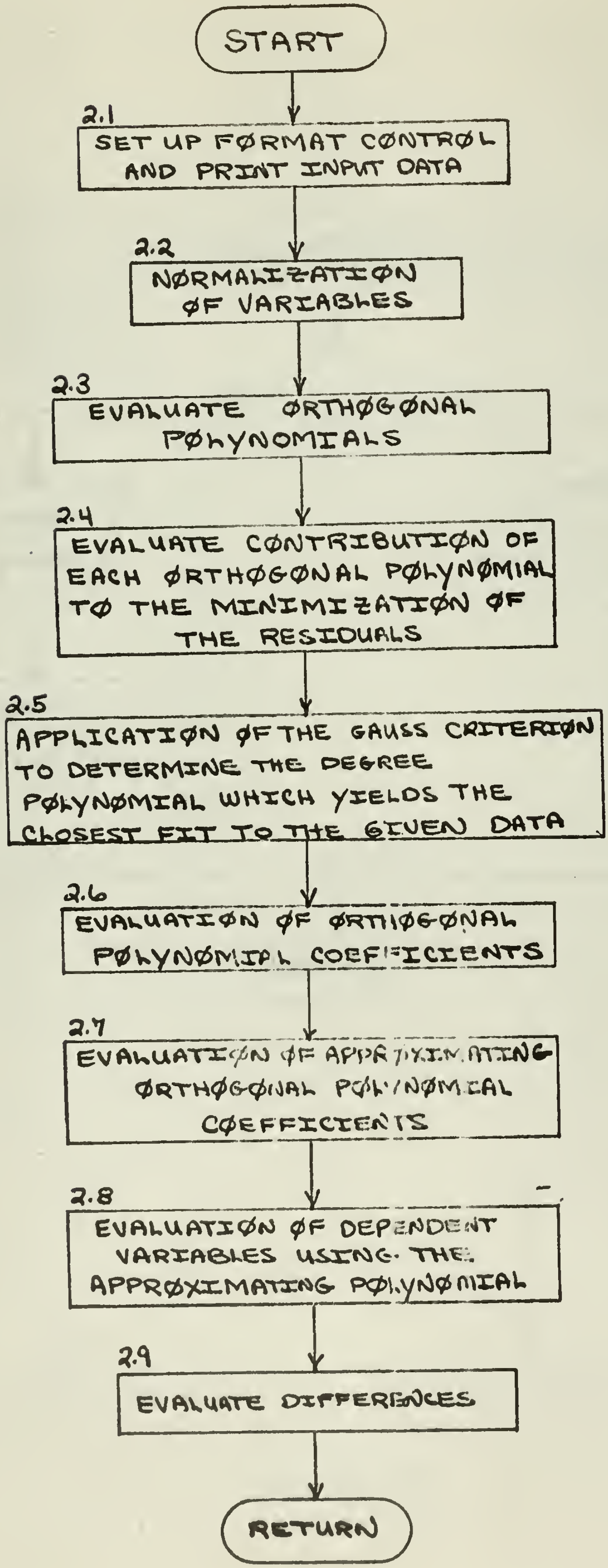

ENTRY
KWT=0?
No
Yes
KWT= ?
1
2
3
READ U(I)
READ W(J)
READ U(I) W(J)
J=1
W(J)=1.
J=J+1
J=JMAX?
No
Yes
I=1
U(I)=1.
I=I+1
I=IMAX?
No
Yes
I=1
U(I)=1.
I=I+1
I=IMAX?
No
Yes
J=1
W(J)=1.
J=J+1
J=JMAX?
No
Yes
CØNTINUE

1.4

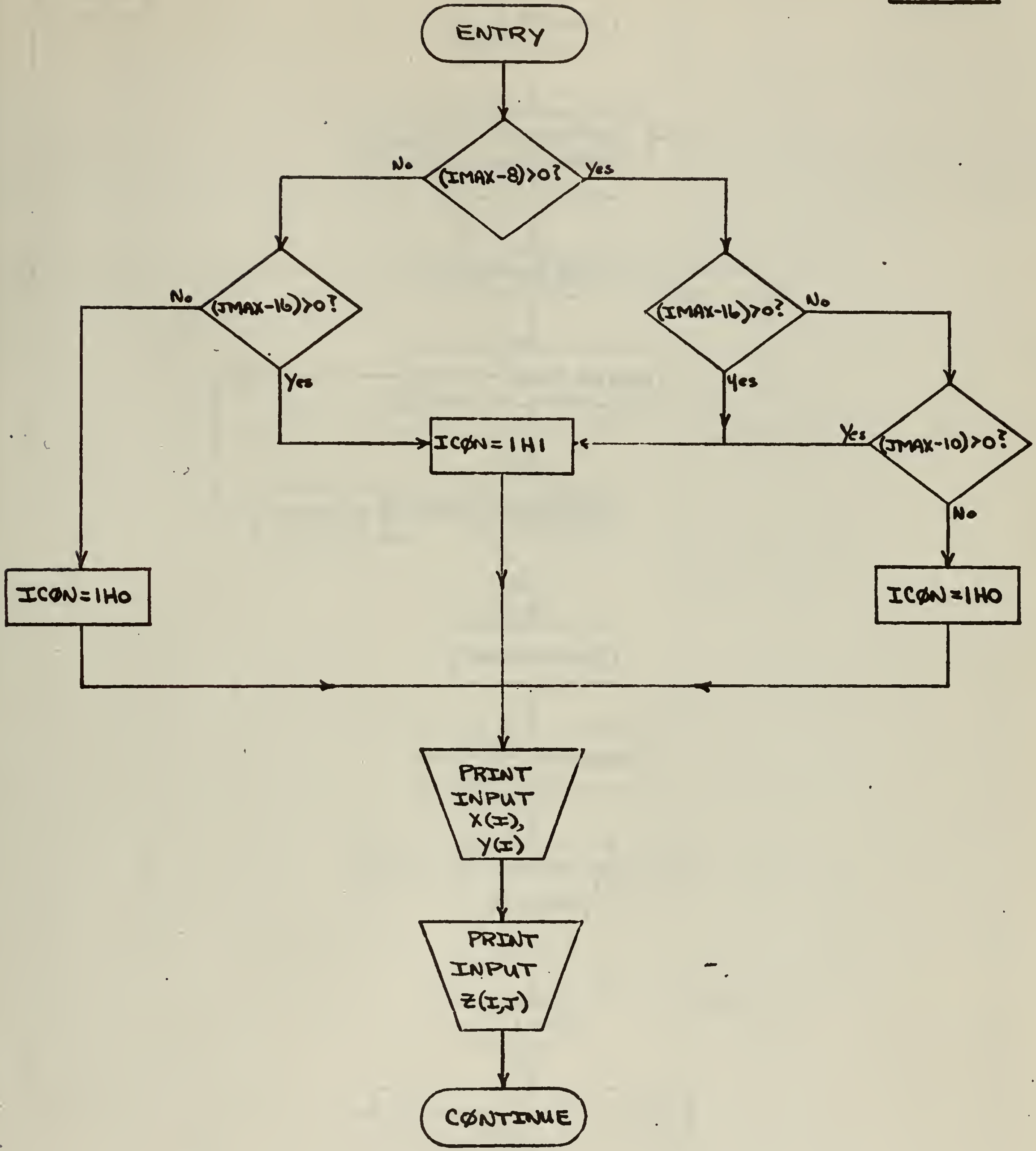


SUBRØUTINE SURFACE

2.0

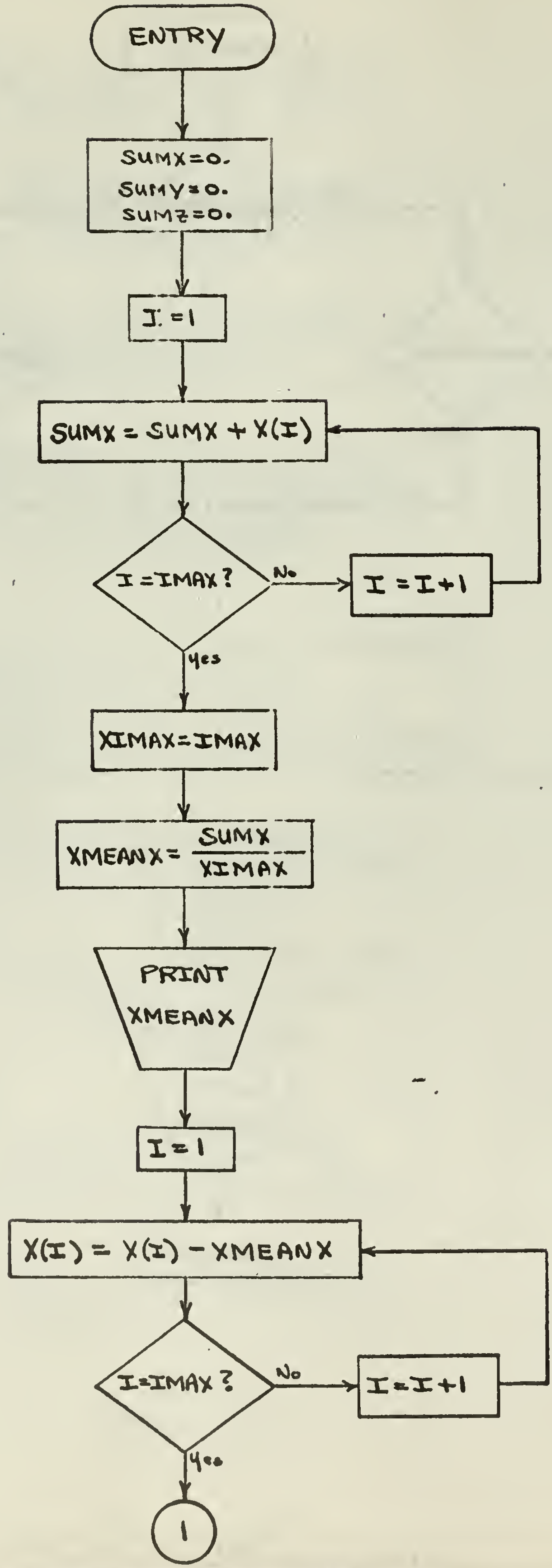


2.1

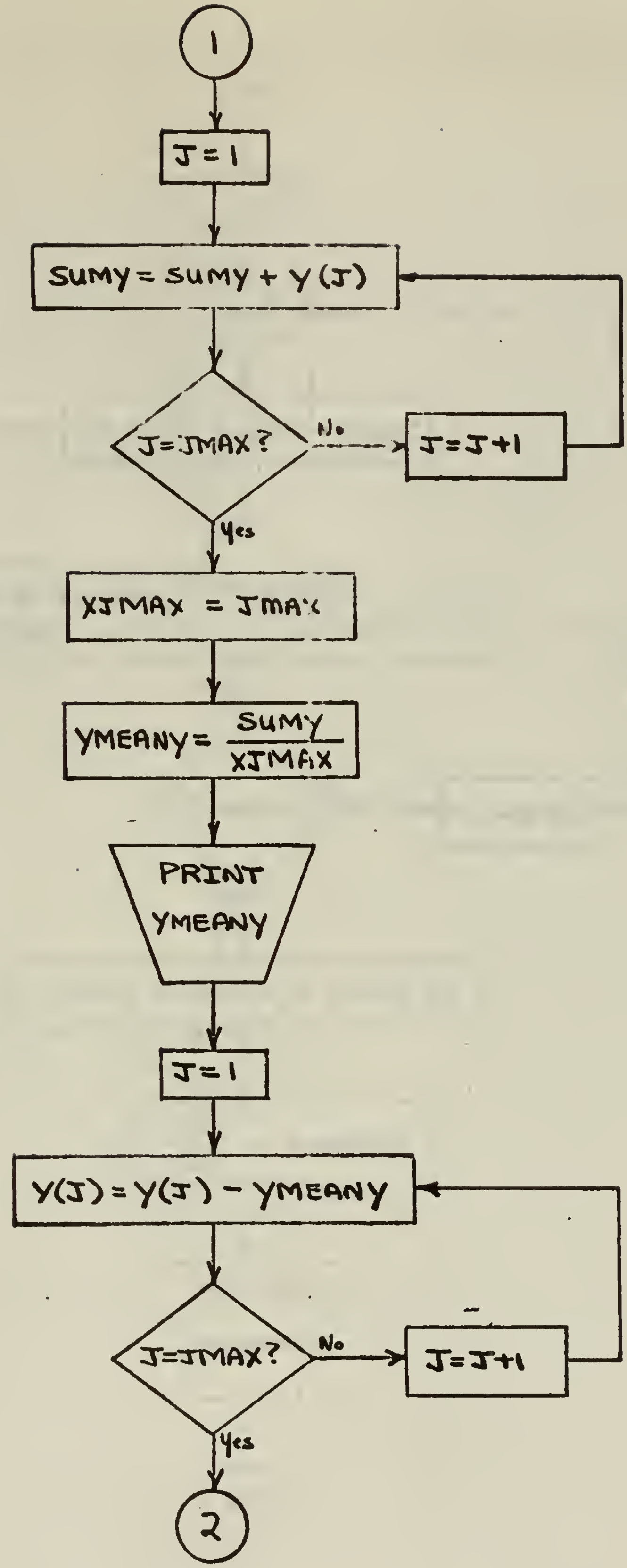


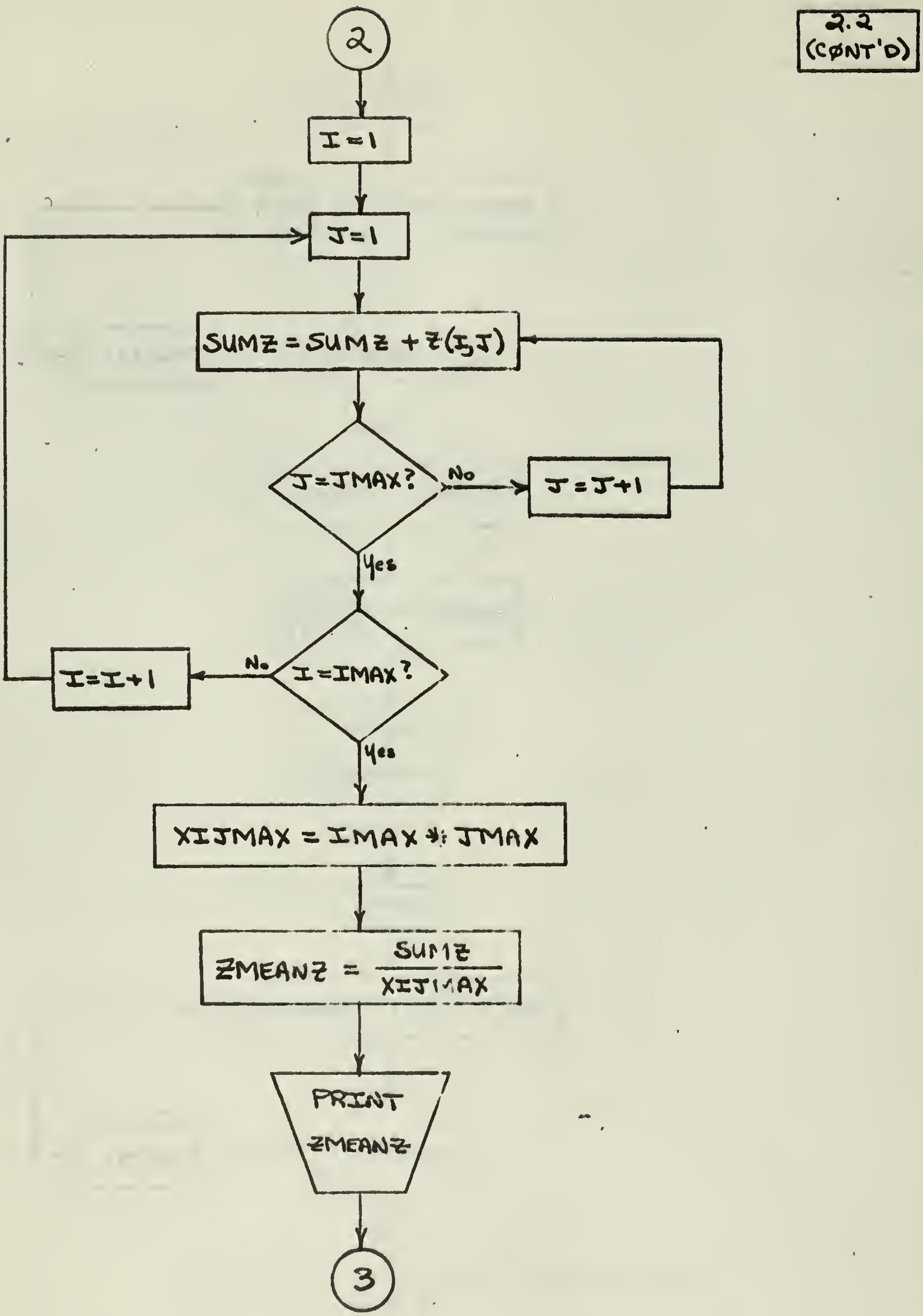
ENTRY
(IMAX-8)>0?
No
Yes
(JMAX-16)>0?
No
Yes
(IMAX-16)>0?
No
Yes
(JMAX-10)>0?
Yes
No
ICØN=1H1
ICON=1H0
ICØN=1H0
PRINT
INPUT
X(I),
Y(I)
PRINT
INPUT
Z(I,J)
CØNTINUE

2.2

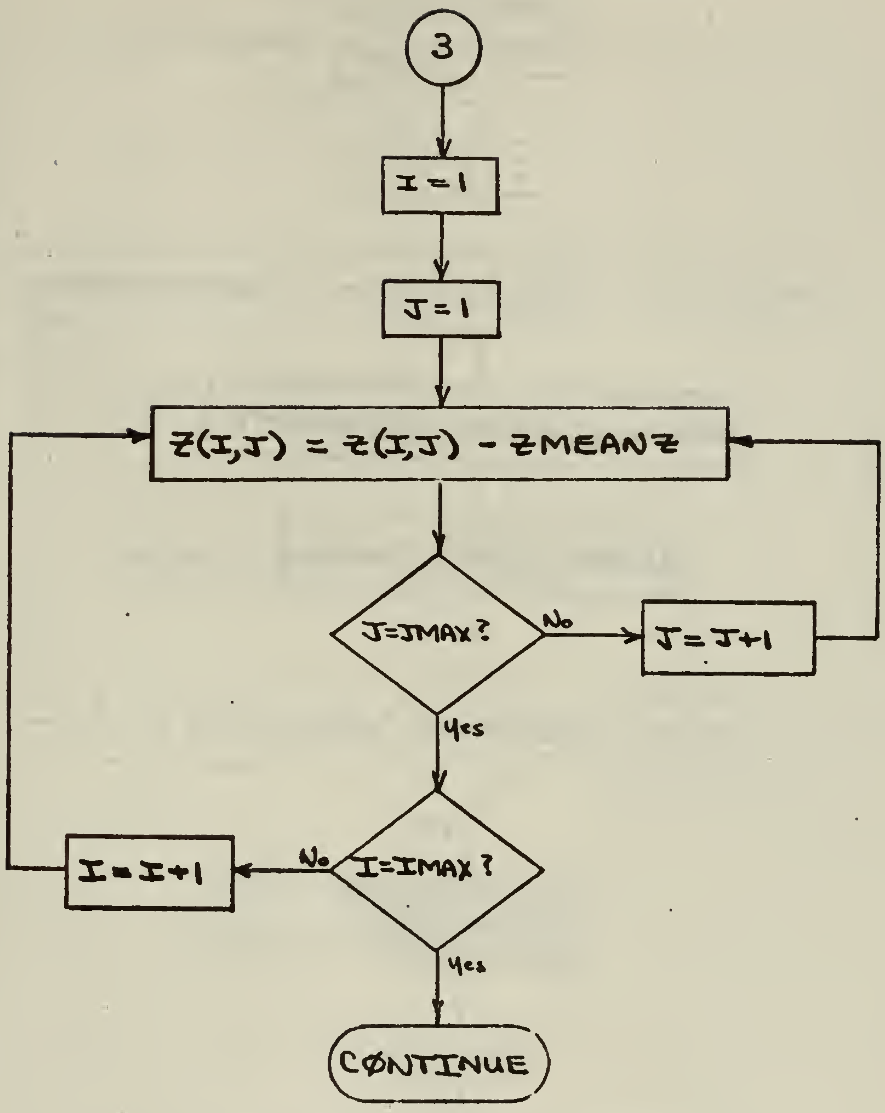

ENTRY
SUMX=0.
SUMY=0.
SUMZ=0.
I=1
SUMX = SUMX + X(I)
I=IMAX?
No
I=I+1
yes
XIMAX=IMAX
XMEANX = SUMX / XIMAX
PRINT
XMEANX
I=1
X(I) = X(I) - XMEANX
I=IMAX?
No
I=I+1
yes
1

2.2 (CONT'D)

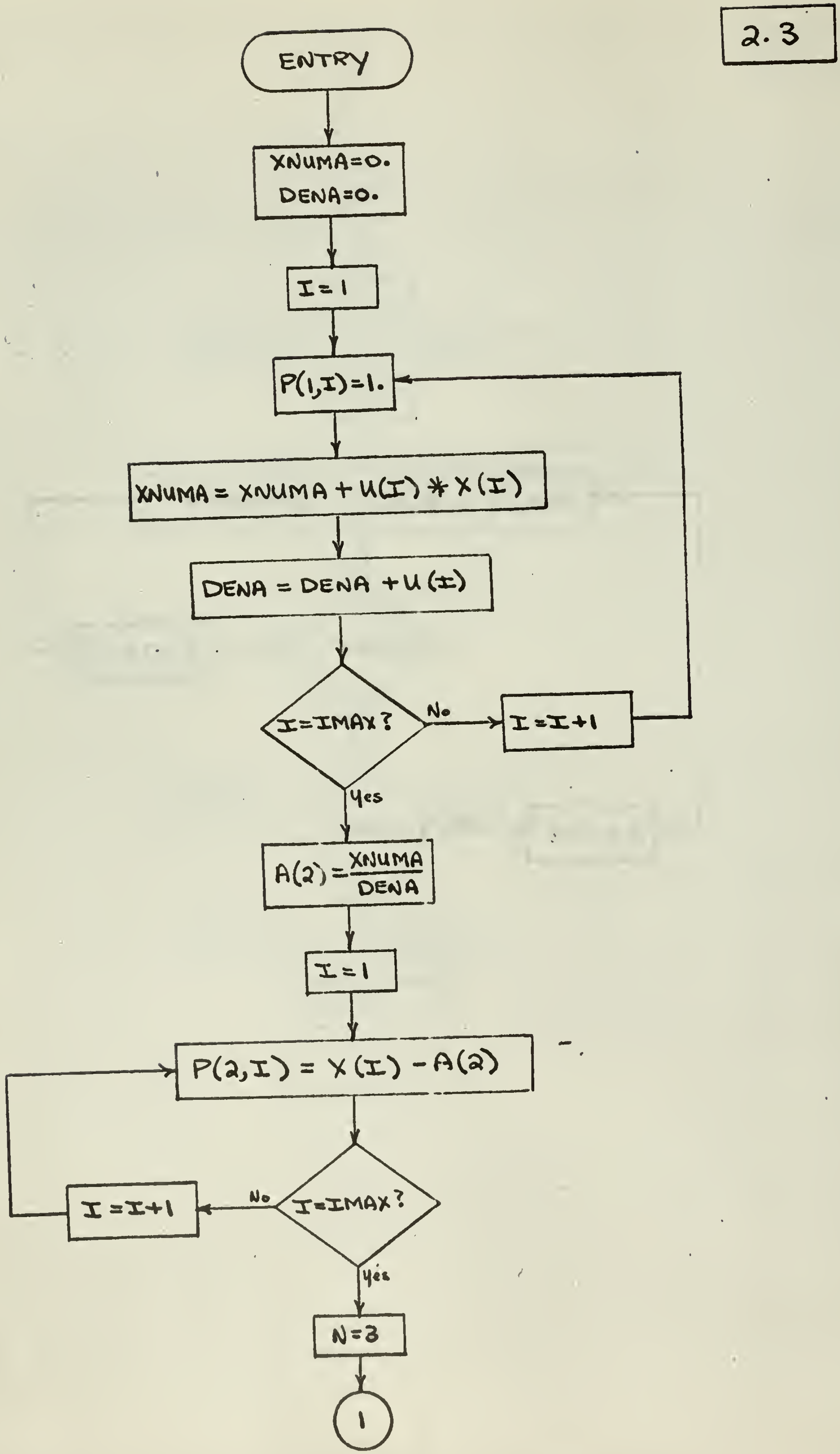

1
J = 1
SUMY = SUMY + Y(J)
J=JMAX?
No
J=J+1
Yes
XJMAX = JMAX
YMEANY = SUMY / XJMAX
PRINT YMEANY
J = 1
Y(J) = Y(J) - YMEANY
J=JMAX?
No
J=J+1
Yes
2


2.2 (CØNT'D)
2
I=1
J=1
SUMZ = SUMZ + Z(I,J)
J=JMAX?
No
J=J+1
Yes
No
I=IMAX?
I=I+1
Yes
XIJMAX = IMAX * JMAX
ZMEANZ = SUMZ / XIJMAX
PRINT ZMEANZ
3

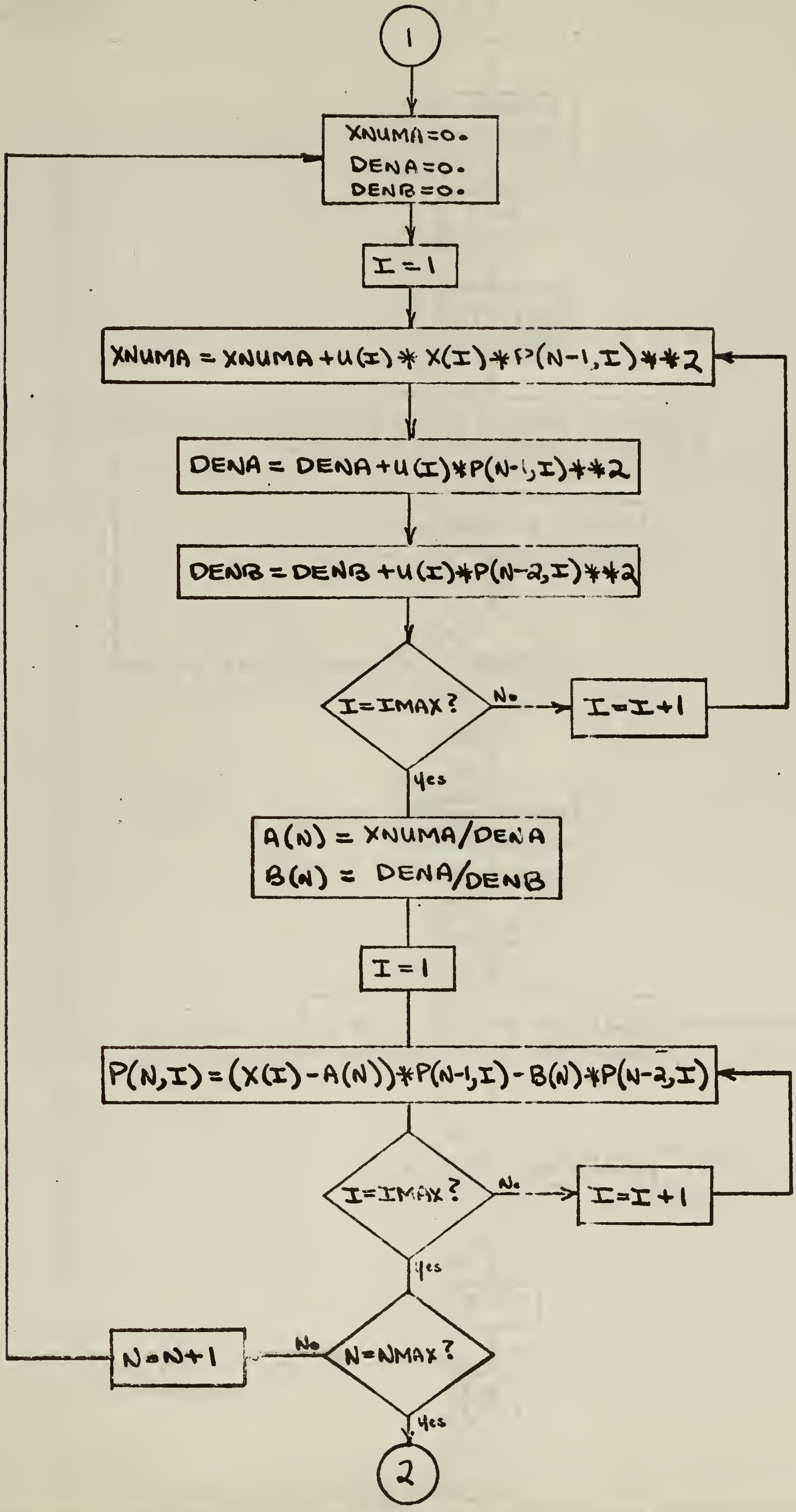
2.2
(CØNT'D)



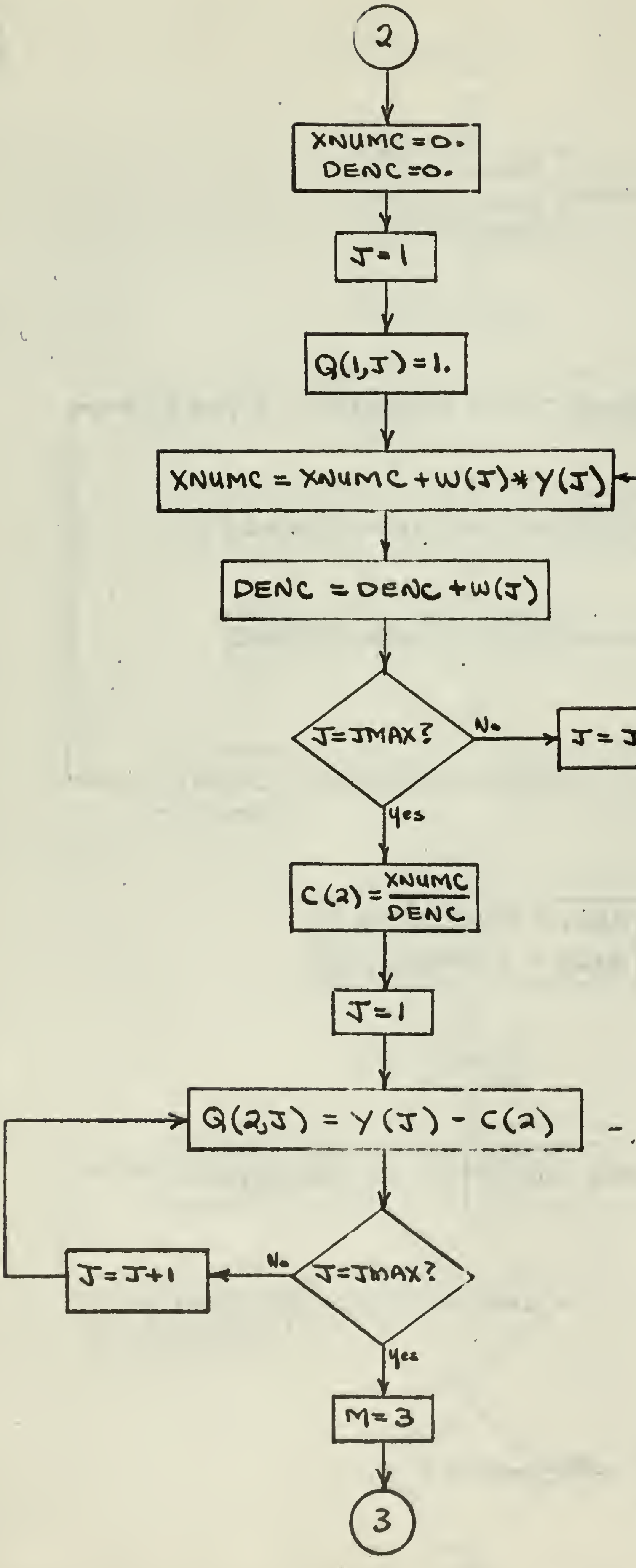
3
I = 1
J = 1
Z(I,J) = Z(I,J) - ZMEANZ
J=JMAX?
No
J = J+1
Yes
I=IMAX?
No
I = I+1
Yes
CØNTINUE


2.3
ENTRY
XNUMA=0.
DENA=0.
I=1
P(1,I)=1.
XNUMA = XNUMA + U(I) * X(I)
DENA = DENA + U(I)
I=IMAX?
No
I=I+1
Yes
A(2) = XNUMA / DENA
I=1
P(2,I) = X(I) - A(2)
I=IMAX?
No
I=I+1
Yes
N=3
1

2.3 (CØNT'D)

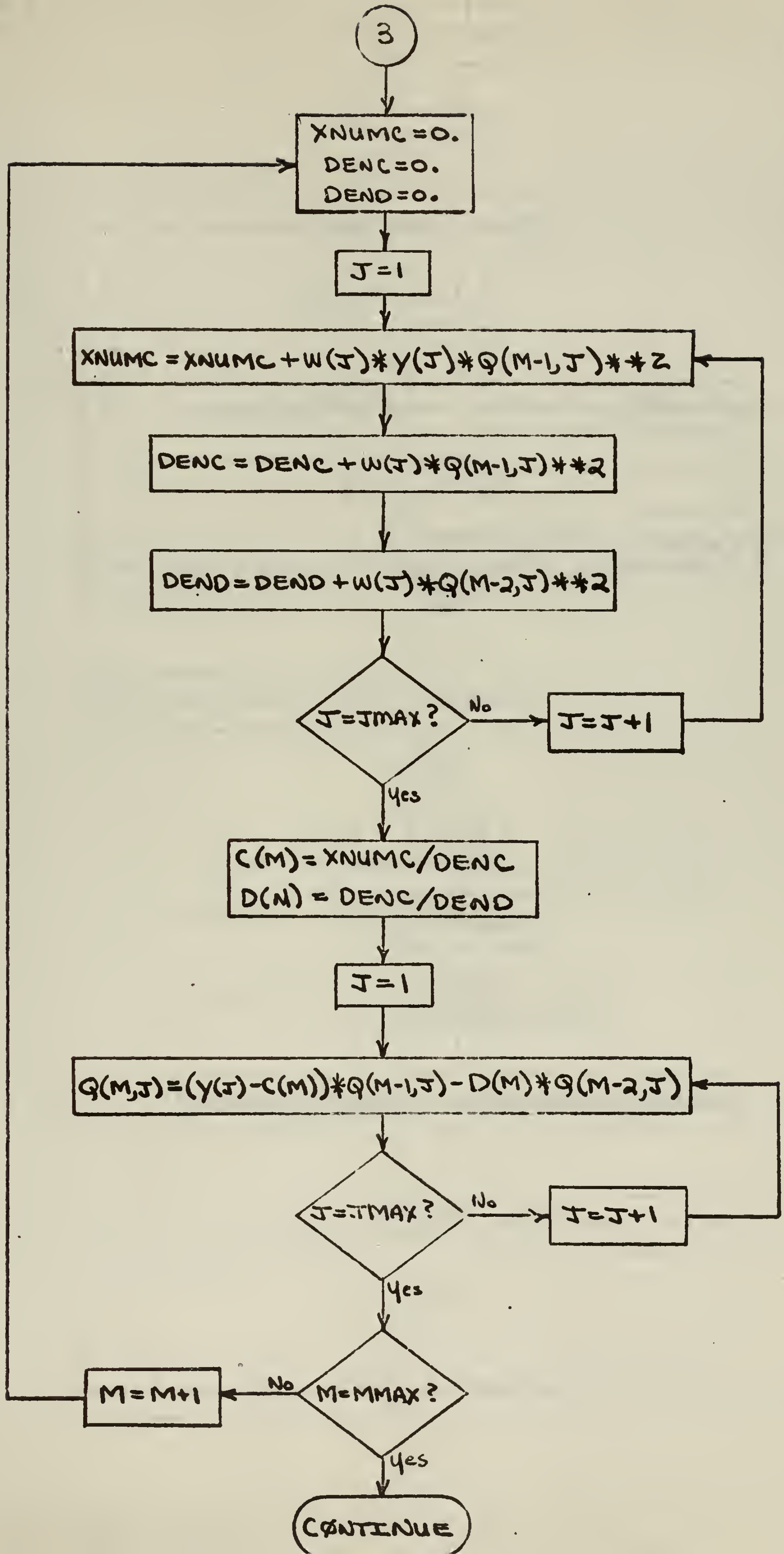

1
XNUMA=0.
DENA=0.
DENB=0.
I=1
XNUMA = XNUMA+U(I)*X(I)*P(N-1,I)**2
DENA = DENA+U(I)*P(N-1,I)**2
DENB = DENB+U(I)*P(N-2,I)**2
I=IMAX?
No
I=I+1
yes
A(N) = XNUMA/DENA
B(N) = DENA/DENB
I=1
P(N,I)=(X(I)-A(N))*P(N-1,I)-B(N)*P(N-2,I)
I=IMAX?
No
I=I+1
yes
N=NMAX?
No
N=N+1
yes
2

2.3
(CØNT'D)



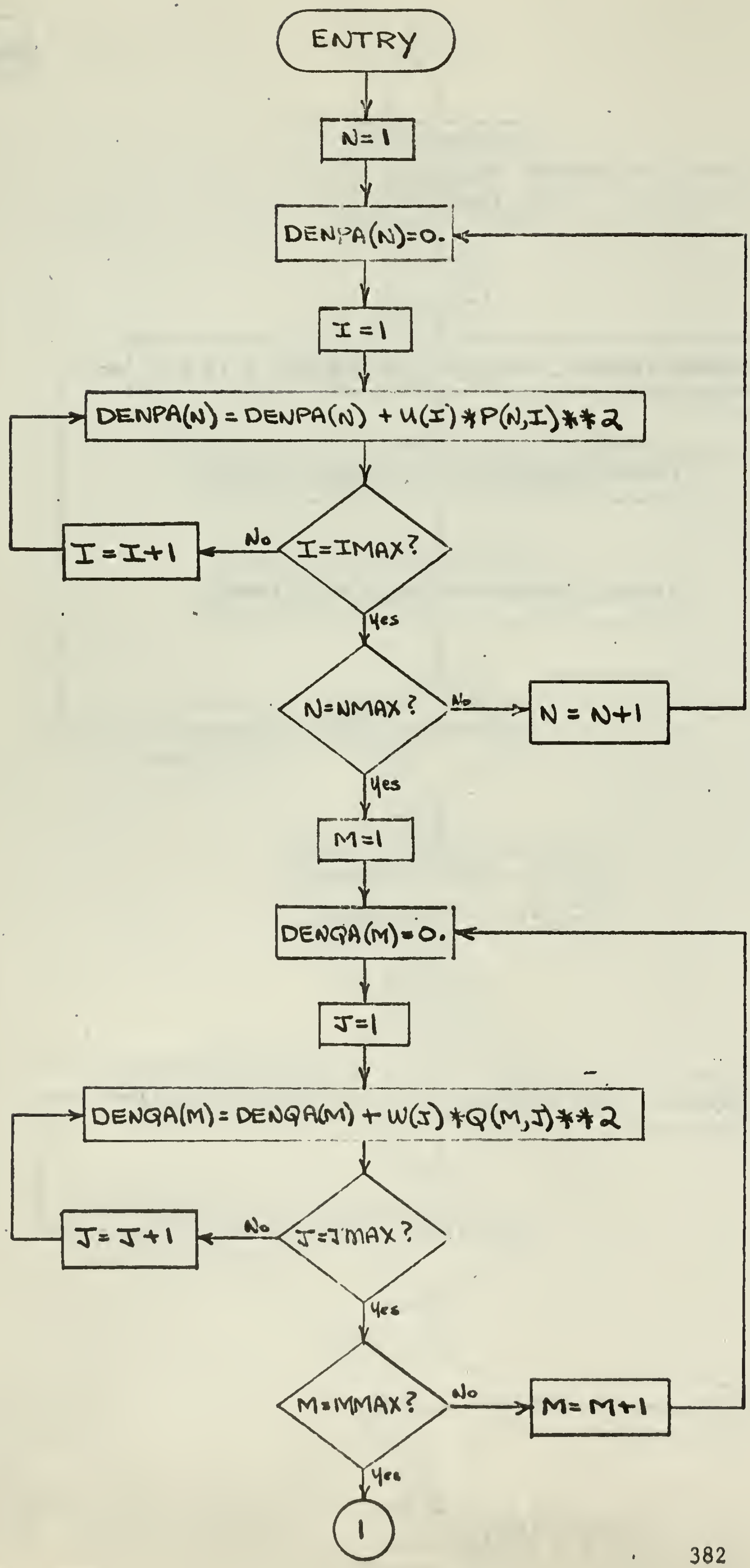
2
XNUMC=0.
DENC=0.
J=1
Q(1,J)=1.
XNUMC = XNUMC + W(J) * Y(J)
DENC = DENC + W(J)
J=JMAX?
No
J = J+1
Yes
C(2) = XNUMC / DENC
J=1
Q(2,J) = Y(J) - C(2)
J=JMAX?
No
J = J+1
Yes
M=3
3

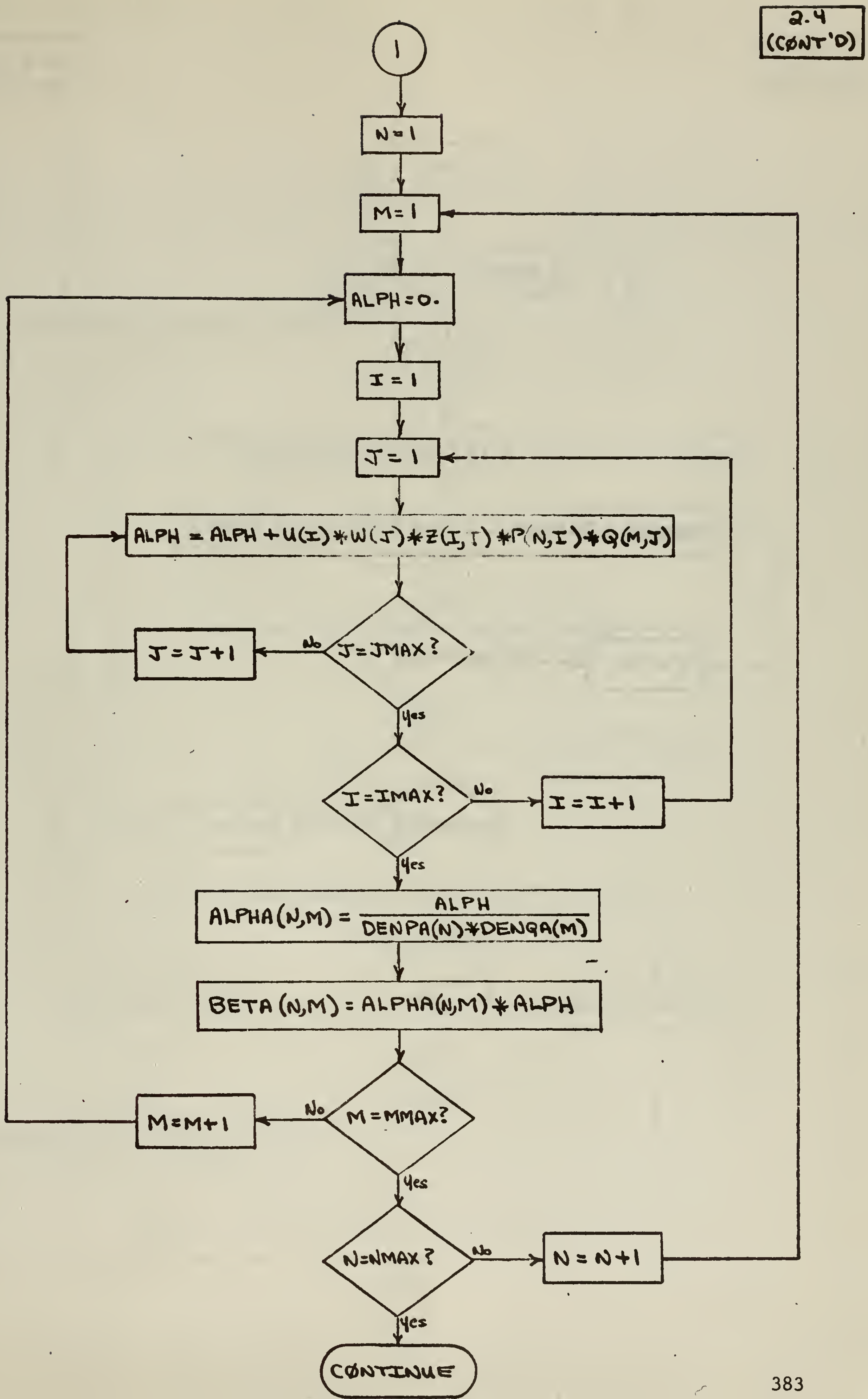
2.3 (CØNT'D)



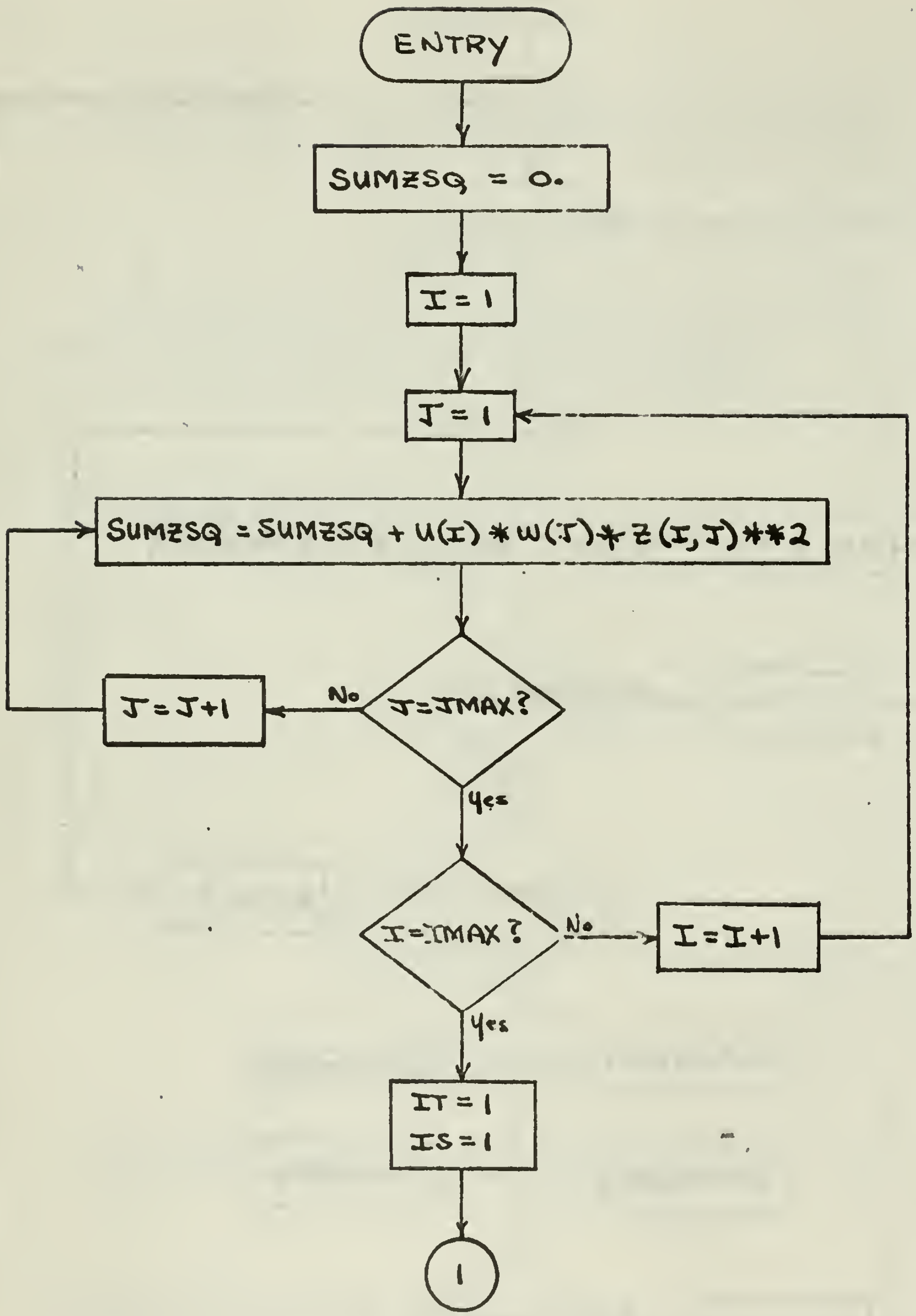
3
XNUMC=0.
DENC=0.
DEND=0.
J=1
XNUMC = XNUMC + W(J)*Y(J)*Q(M-1,J)**2
DENC = DENC + W(J)*Q(M-1,J)**2
DEND = DEND + W(J)*Q(M-2,J)**2
J=JMAX?
No
J=J+1
Yes
C(M)=XNUMC/DENC
D(N) = DENC/DEND
J=1
Q(M,J)=(Y(J)-C(M))*Q(M-1,J)-D(M)*Q(M-2,J)
J=JMAX?
No
J=J+1
Yes
M=MMAX?
No
M=M+1
Yes
CØNTINUE

2.4

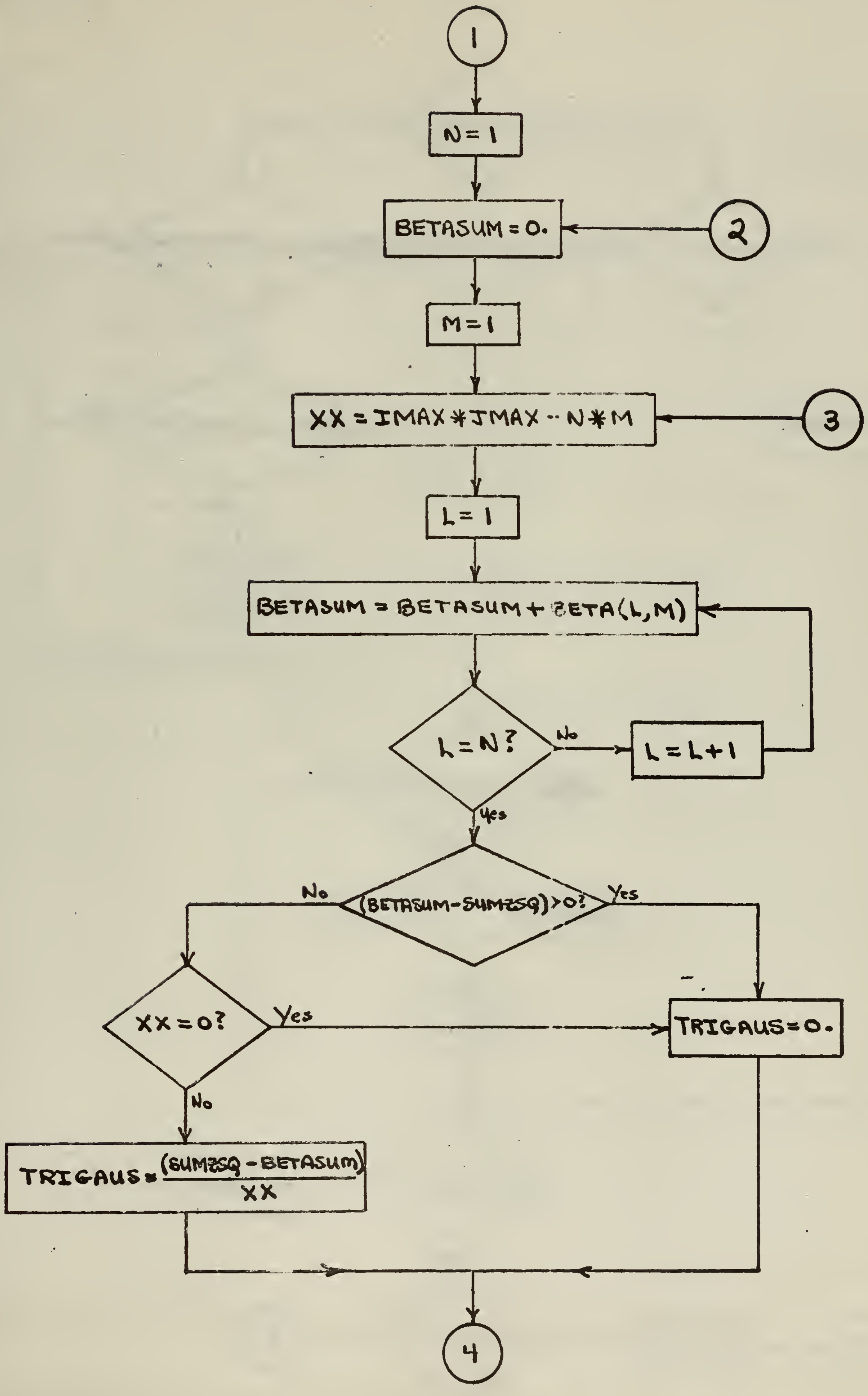

ENTRY
N=1
DENPA(N)=0.
I=1
DENPA(N) = DENPA(N) + U(I)*P(N,I)**2
I=IMAX?
No
I=I+1
Yes
N=NMAX?
No
N = N+1
Yes
M=1
DENQA(M)=0.
J=1
DENQA(M)=DENQA(M) + W(J)*Q(M,J)**2
J=JMAX?
No
J=J+1
Yes
M=MMAX?
No
M=M+1
Yes
1



2.4 (CØNT'D)
1
N=1
M=1
ALPH=0.
I=1
J=1
ALPH = ALPH + U(I)*W(J)*Z(I,J)*P(N,I)*Q(M,J)
J=JMAX?
No
J=J+1
Yes
I=IMAX?
No
I=I+1
Yes
ALPHA(N,M) = ALPH / DENPA(N)*DENQA(M)
BETA(N,M) = ALPHA(N,M)*ALPH
M=MMAX?
No
M=M+1
Yes
N=NMAX?
No
N=N+1
Yes
CØNTINUE

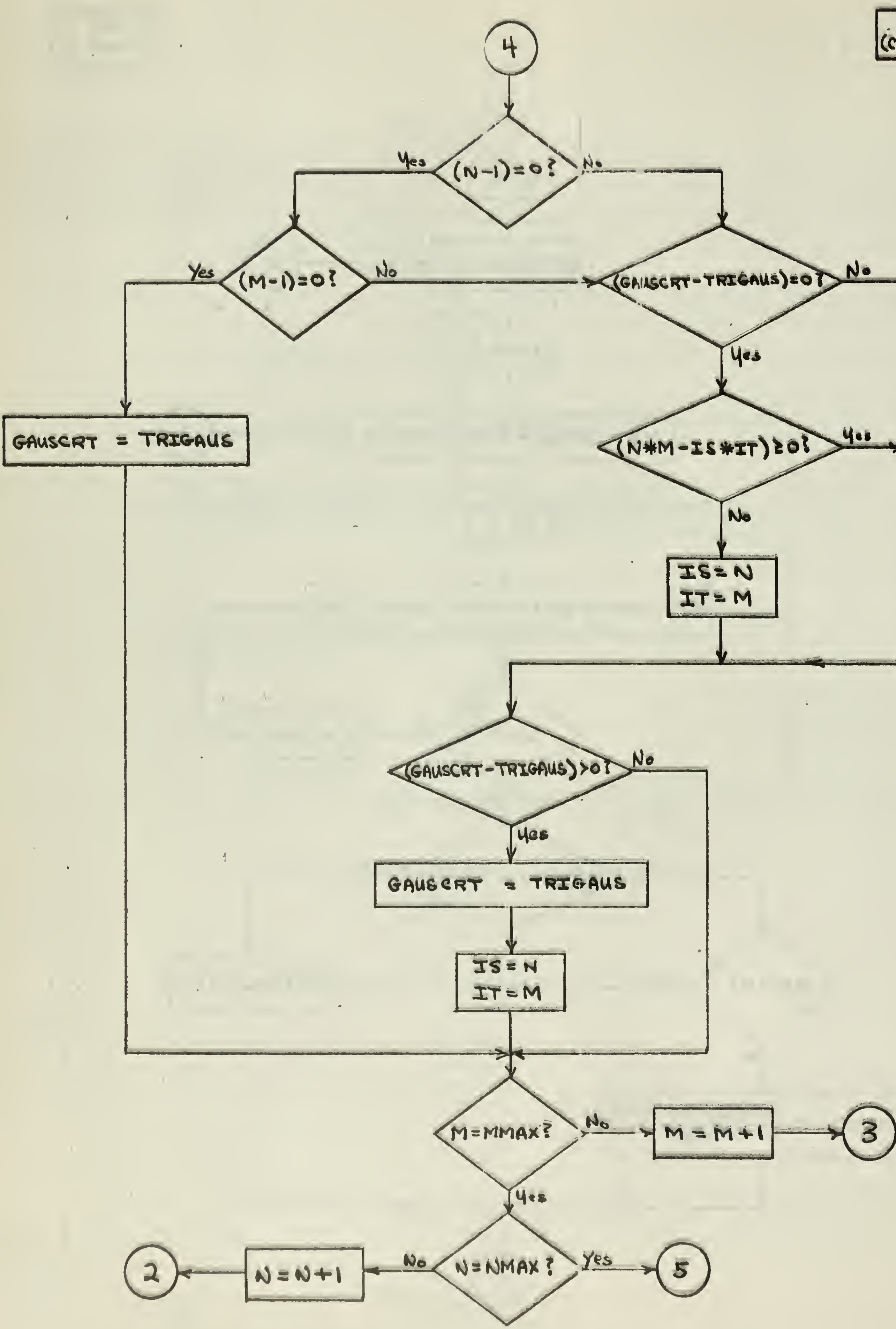

ENTRY
SUMZSQ = 0.
I = 1
J = 1
SUMZSQ = SUMZSQ + U(I) * W(J) * Z(I,J) ** 2
J = JMAX?
No
J = J+1
Yes
I = IMAX?
No
I = I+1
Yes
IT = 1
IS = 1
1

2.5 (CØNT'D)

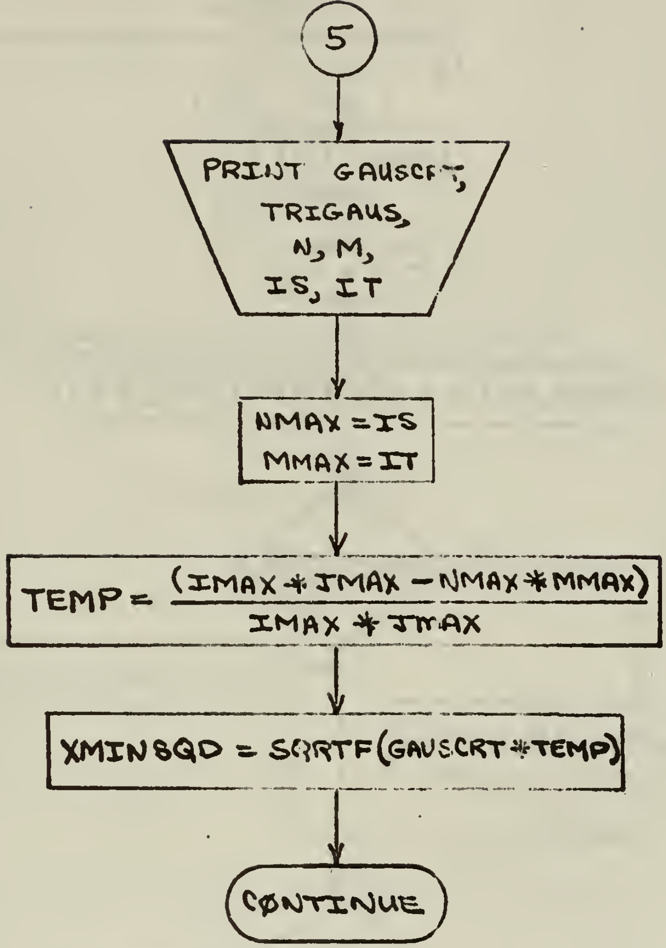


1
N = 1
BETASUM = 0.
2
M = 1
XX = IMAX*JMAX - N*M
3
L = 1
BETASUM = BETASUM + BETA(L,M)
L = N?
No
L = L+1
Yes
(BETASUM-SUMZSQ) > 0?
No
Yes
XX = 0?
Yes
No
TRIGAUS = 0.
TRIGAUS = (SUMZSQ - BETASUM) / XX
4

2.5 (CØNT'D)

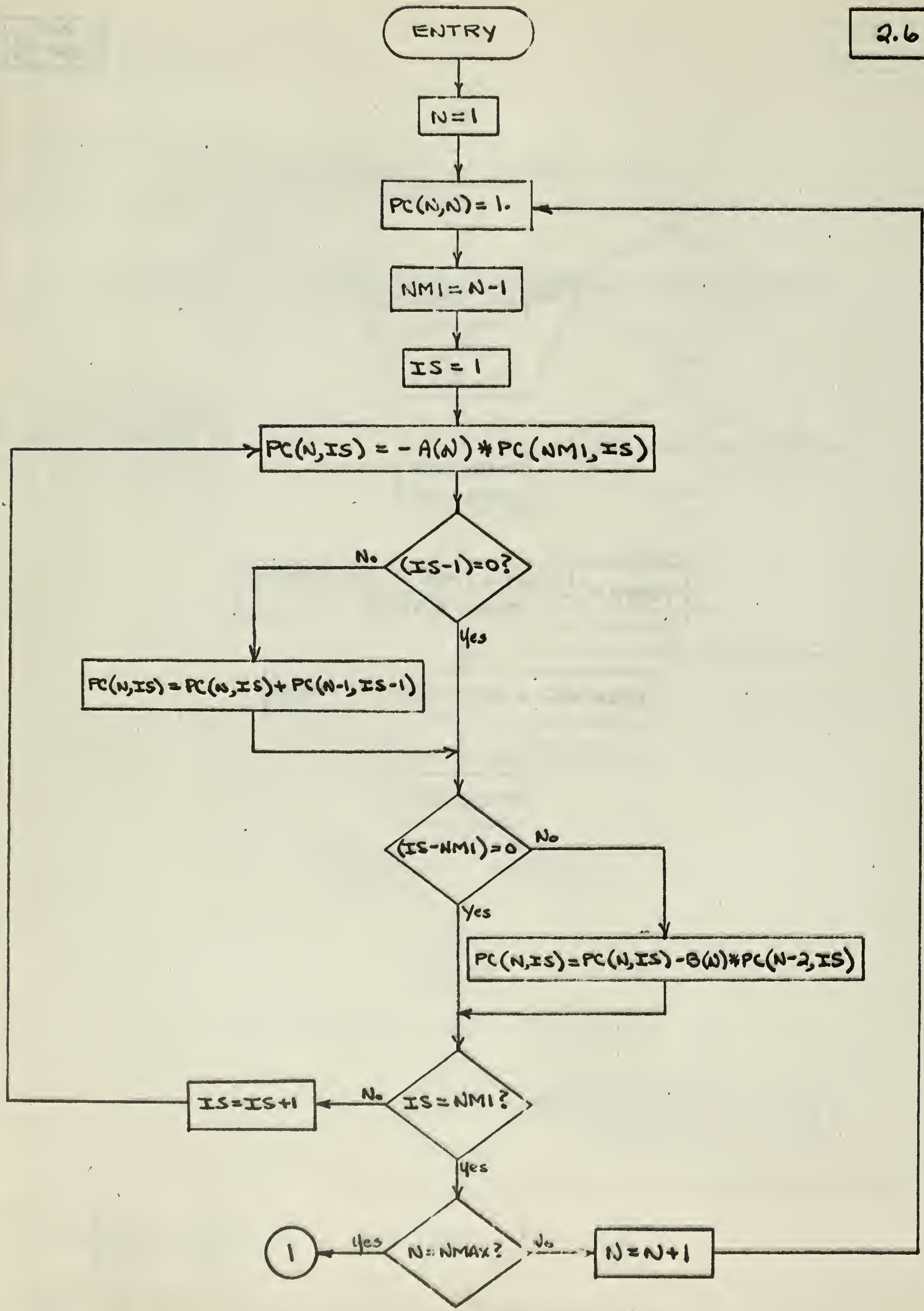

4
(N-1)=0?
Yes
No
(M-1)=0?
Yes
No
(GAUSCRT-TRIGAUS)=0?
No
Yes
GAUSCRT = TRIGAUS
(N*M-IS*IT)≥0?
Yes
No
IS=N
IT=M
(GAUSCRT-TRIGAUS)>0?
No
Yes
GAUSCRT = TRIGAUS
IS=N
IT=M
M=MMAX?
No
M = M+1
3
Yes
N=NMAX?
No
N=N+1
2
Yes
5

2.5
(CØNT'D)

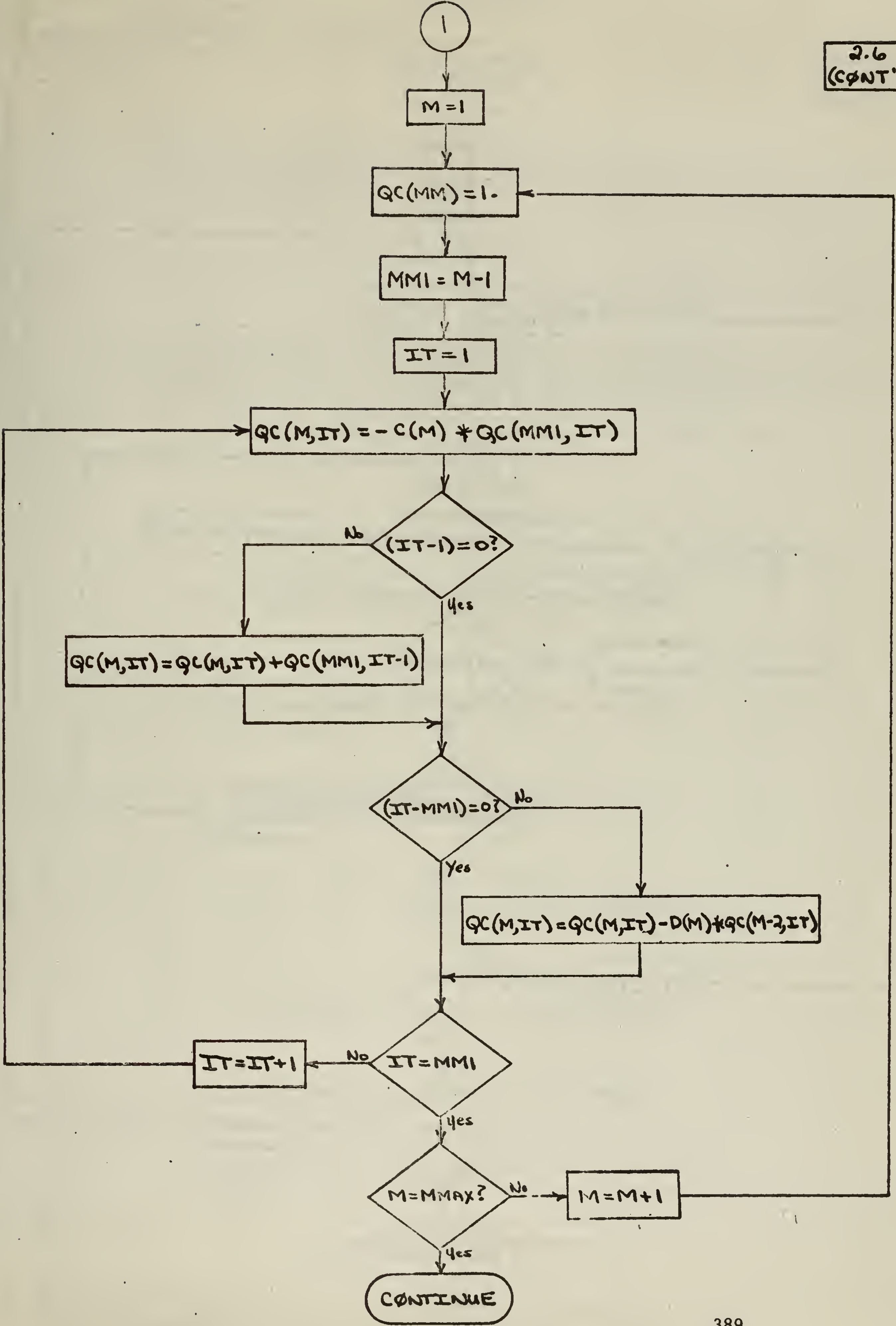


5
PRINT GAUSCRT, TRIGAUS, N, M, IS, IT
NMAX = IS
MMAX = IT
TEMP = (IMAX * JMAX − NMAX * MMAX) / IMAX * JMAX
XMINSQD = SQRTF(GAUSCRT * TEMP)
CØNTINUE

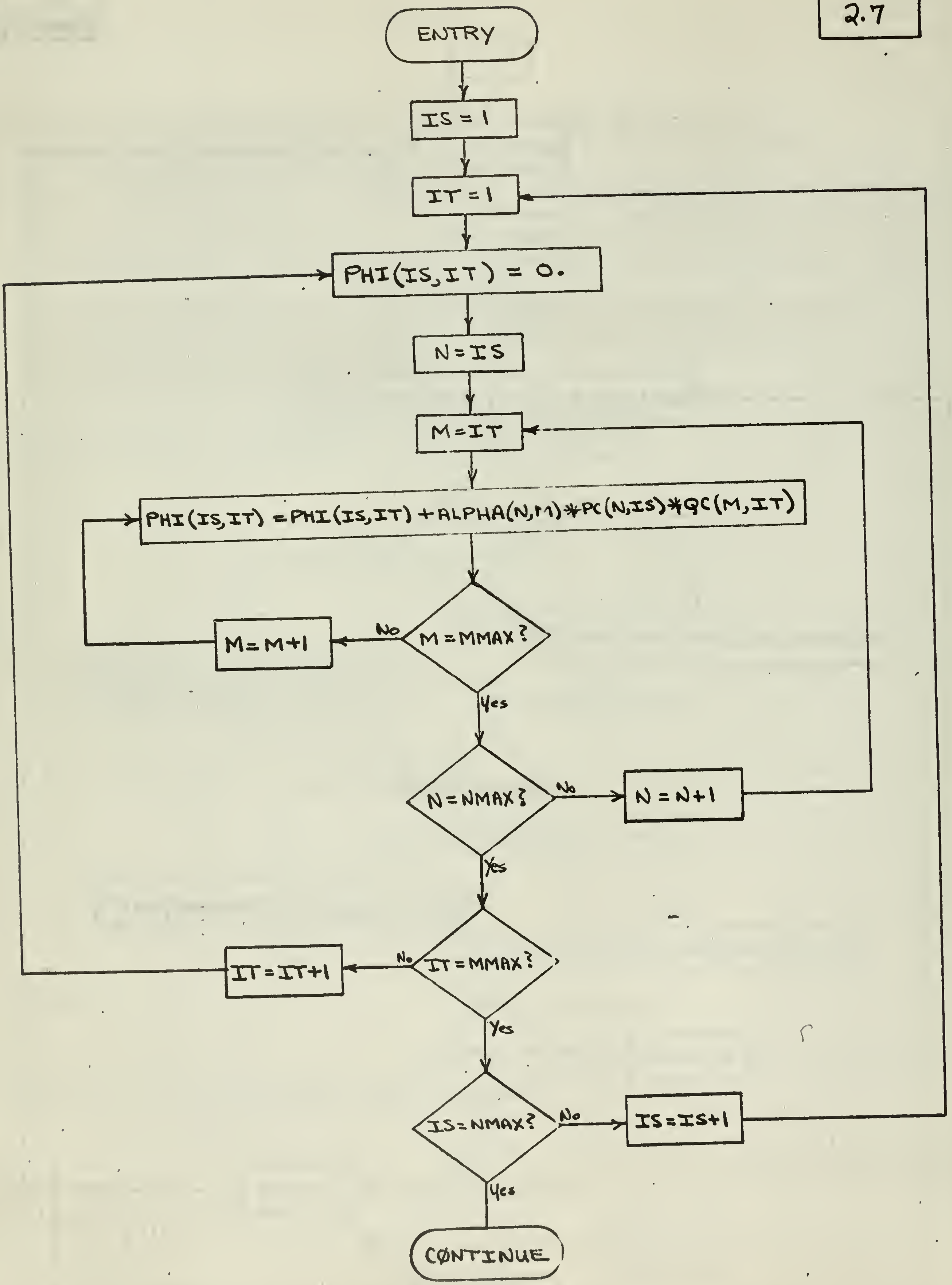
2.6


ENTRY
N=1
PC(N,N)=1.
NM1=N-1
IS=1
PC(N,IS) = - A(N)*PC(NM1,IS)
(IS-1)=0?
No
Yes
PC(N,IS)=PC(N,IS)+PC(N-1,IS-1)
(IS-NM1)=0
No
Yes
PC(N,IS)=PC(N,IS)-B(N)*PC(N-2,IS)
IS=NM1?
No
IS=IS+1
Yes
N=NMAX?
Yes
1
No
N=N+1

2.6 (CØNT'D)

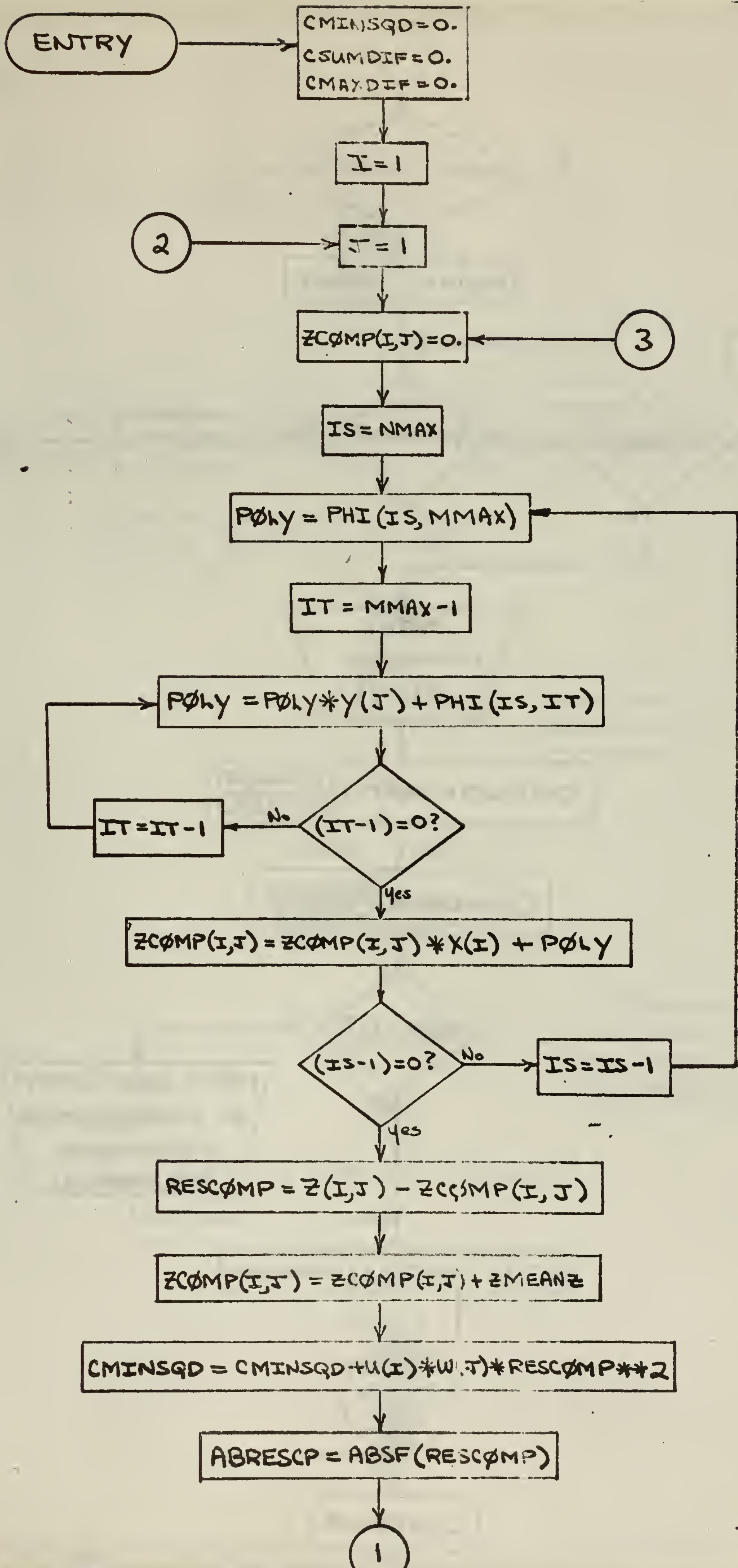

1
M = 1
QC(MM) = 1.
MM1 = M-1
IT = 1
QC(M,IT) = - C(M) * QC(MM1, IT)
(IT-1) = 0?
No
Yes
QC(M,IT) = QC(M,IT) + QC(MM1, IT-1)
(IT-MM1) = 0?
No
Yes
QC(M,IT) = QC(M,IT) - D(M) * QC(M-2, IT)
IT = MM1
No
IT = IT+1
Yes
M = MMAX?
No
M = M+1
Yes
CØNTINUE

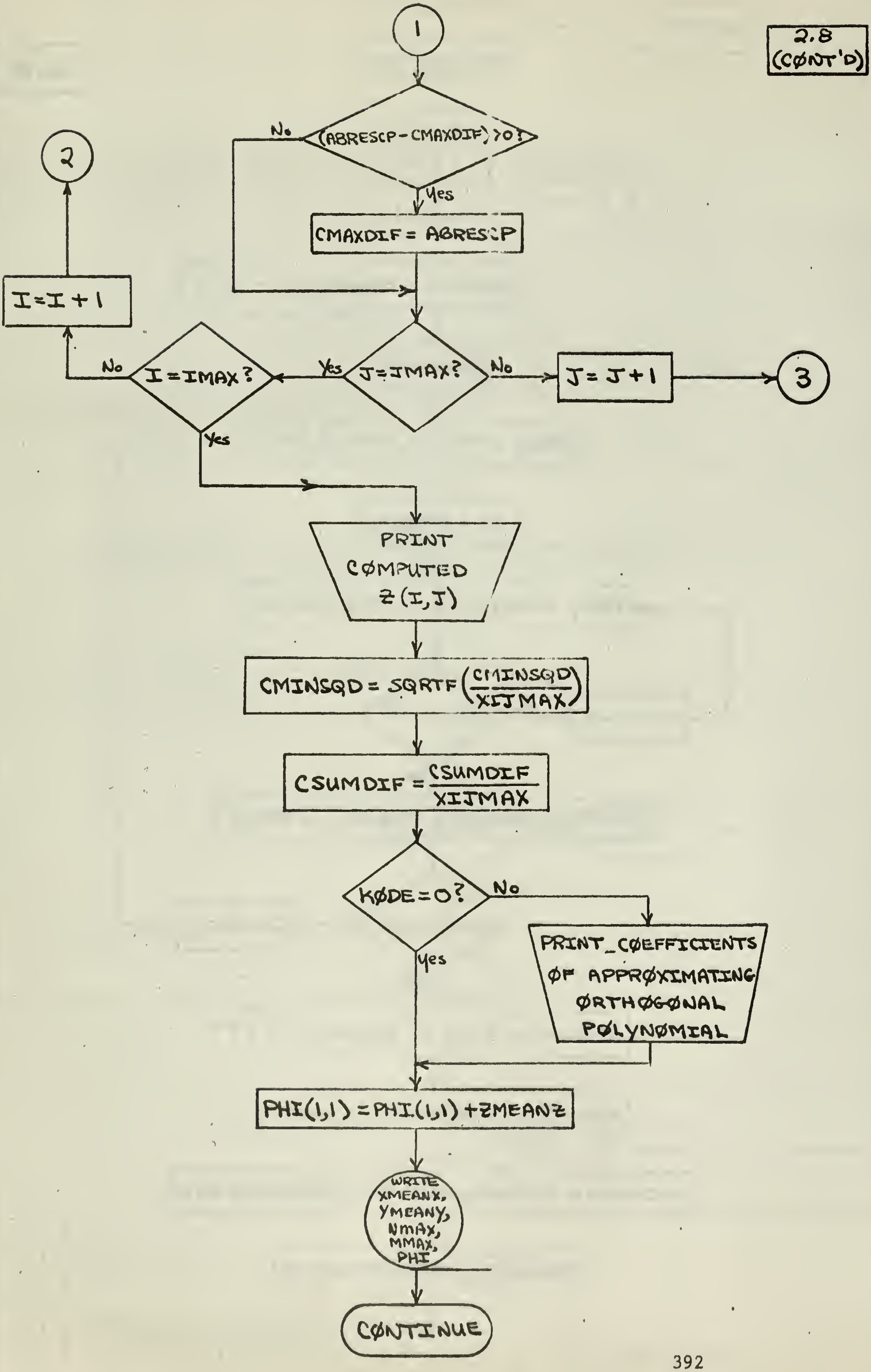
2.7

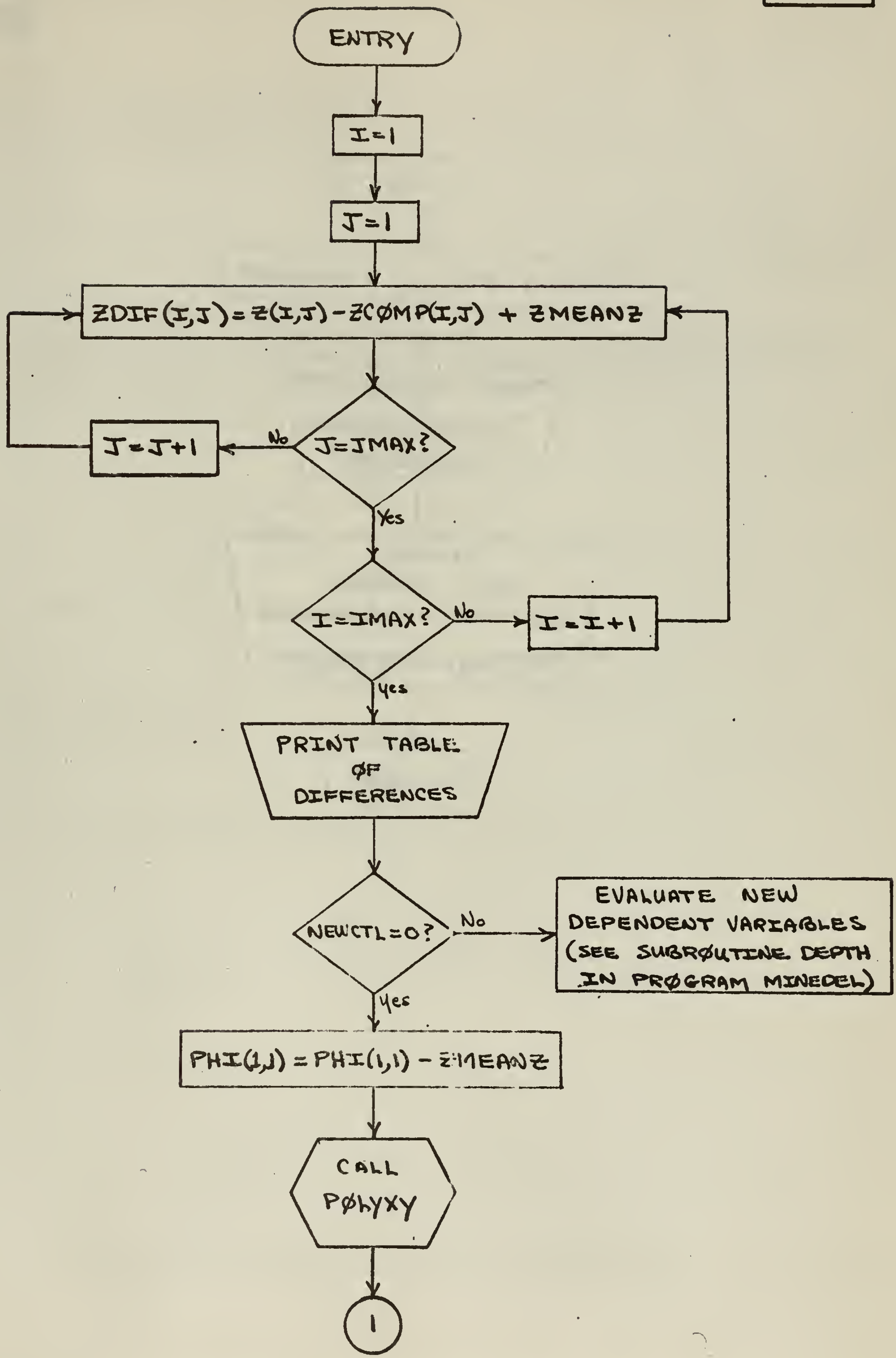


ENTRY
IS = 1
IT = 1
PHI(IS,IT) = 0.
N = IS
M = IT
PHI(IS,IT) = PHI(IS,IT) + ALPHA(N,M) * PC(N,IS) * QC(M,IT)
M = MMAX?
No
M = M+1
Yes
N = NMAX?
No
N = N+1
Yes
IT = MMAX?
No
IT = IT+1
Yes
IS = NMAX?
No
IS = IS+1
Yes
CØNTINUE

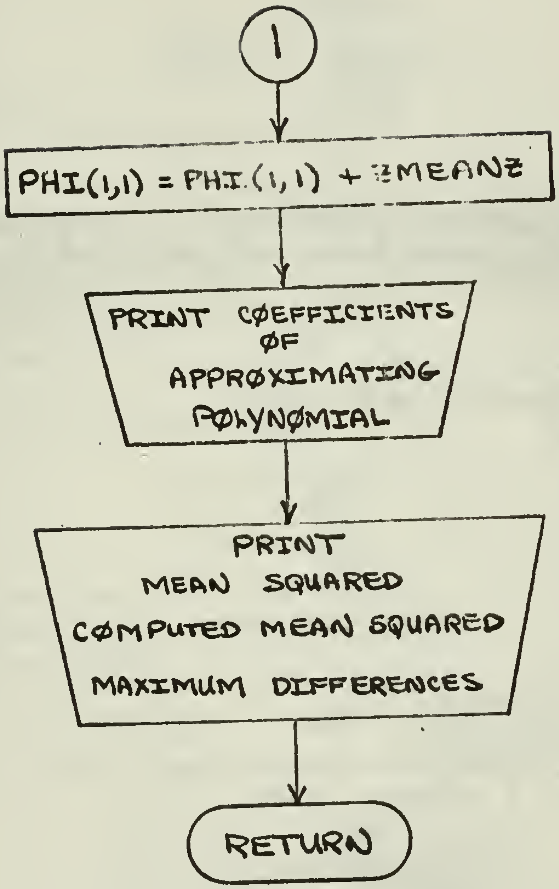
2.8


ENTRY
CMINSQD=0.
CSUMDIF=0.
CMAXDIF=0.
I=1
2
J=1
ZCØMP(I,J)=0.
3
IS=NMAX
PØLY = PHI(IS,MMAX)
IT = MMAX-1
PØLY = PØLY*Y(J) + PHI(IS,IT)
(IT-1)=0?
No
IT=IT-1
Yes
ZCØMP(I,J) = ZCØMP(I,J) * X(I) + PØLY
(IS-1)=0?
No
IS=IS-1
Yes
RESCØMP = Z(I,J) - ZCØMP(I,J)
ZCØMP(I,J) = ZCØMP(I,J) + ZMEANZ
CMINSQD = CMINSQD + U(I)*W(J)*RESCØMP**2
ABRESCP = ABSF(RESCØMP)
1

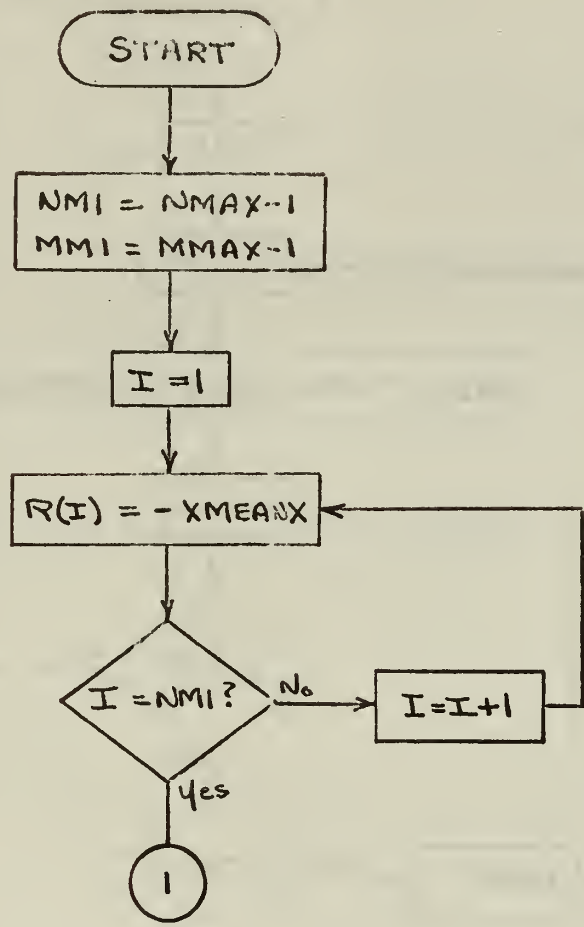

2.8 (CØNT'D)
1
(ABRESCP - CMAXDIF) >0?
No
Yes
CMAXDIF = ABRESCP
2
I=I+1
No
I=IMAX?
Yes
J=JMAX?
No
J= J+1
3
Yes
PRINT CØMPUTED Z(I,J)
CMINSQD = SQRTF(CMINSQD / XIJMAX)
CSUMDIF = CSUMDIF / XIJMAX
KØDE=0?
No
PRINT COEFFICIENTS ØF APPRØXIMATING ØRTHØGØNAL PØLYNØMIAL
Yes
PHI(1,1) = PHI(1,1) + ZMEANZ
WRITE XMEANX, YMEANY, NMAX, MMAX, PHI
CØNTINUE

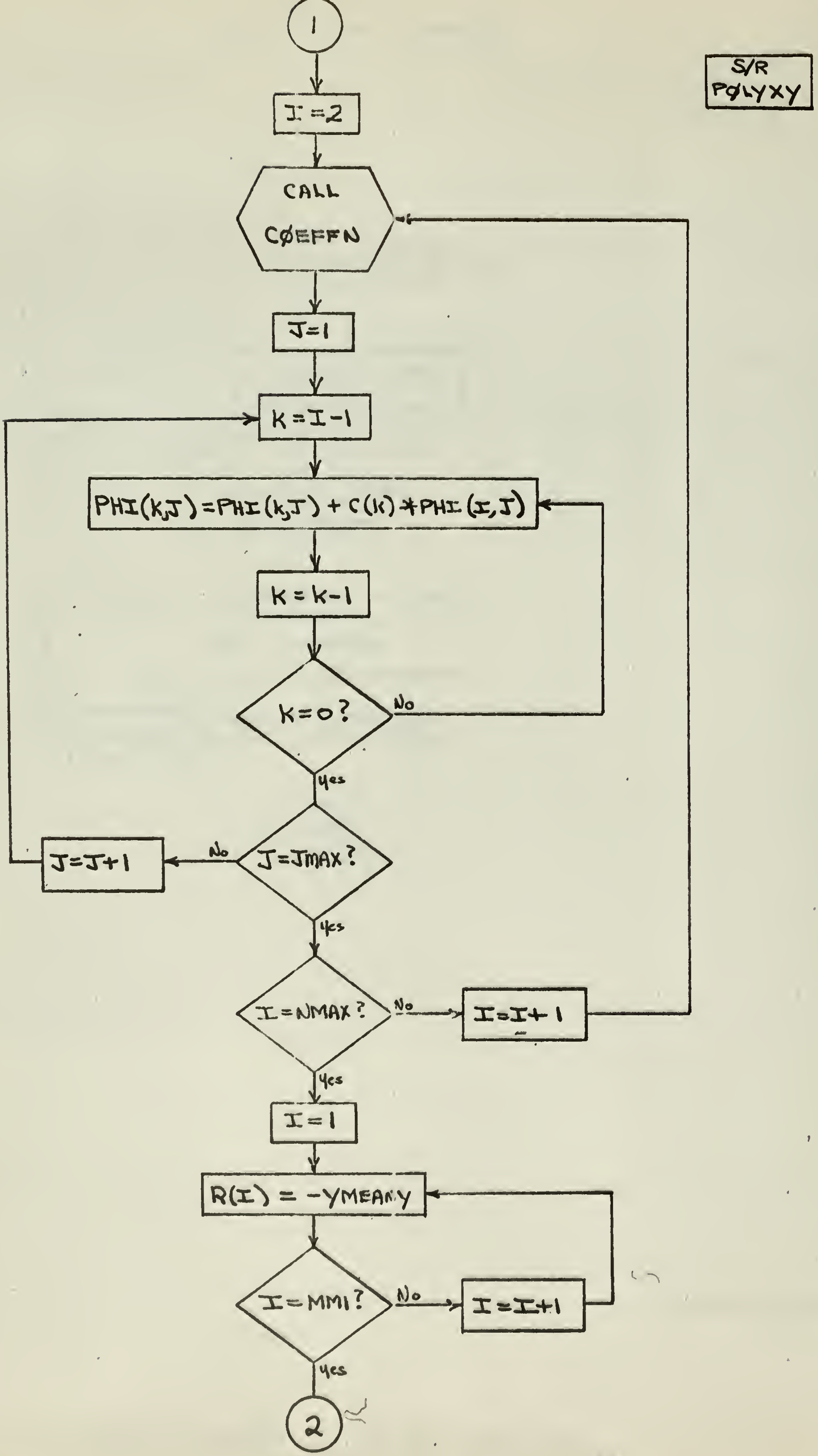

ENTRY
I=1
J=1
ZDIF(I,J) = Z(I,J) - ZCØMP(I,J) + ZMEANZ
J=JMAX?
No
J=J+1
Yes
I=IMAX?
No
I=I+1
Yes
PRINT TABLE ØF DIFFERENCES
NEWCTL=0?
No
EVALUATE NEW DEPENDENT VARIABLES (SEE SUBRØUTINE DEPTH IN PRØGRAM MINEDEL)
Yes
PHI(I,J) = PHI(I,J) - ZMEANZ
CALL PØLYXY
1

2.9 (CØNT'D)

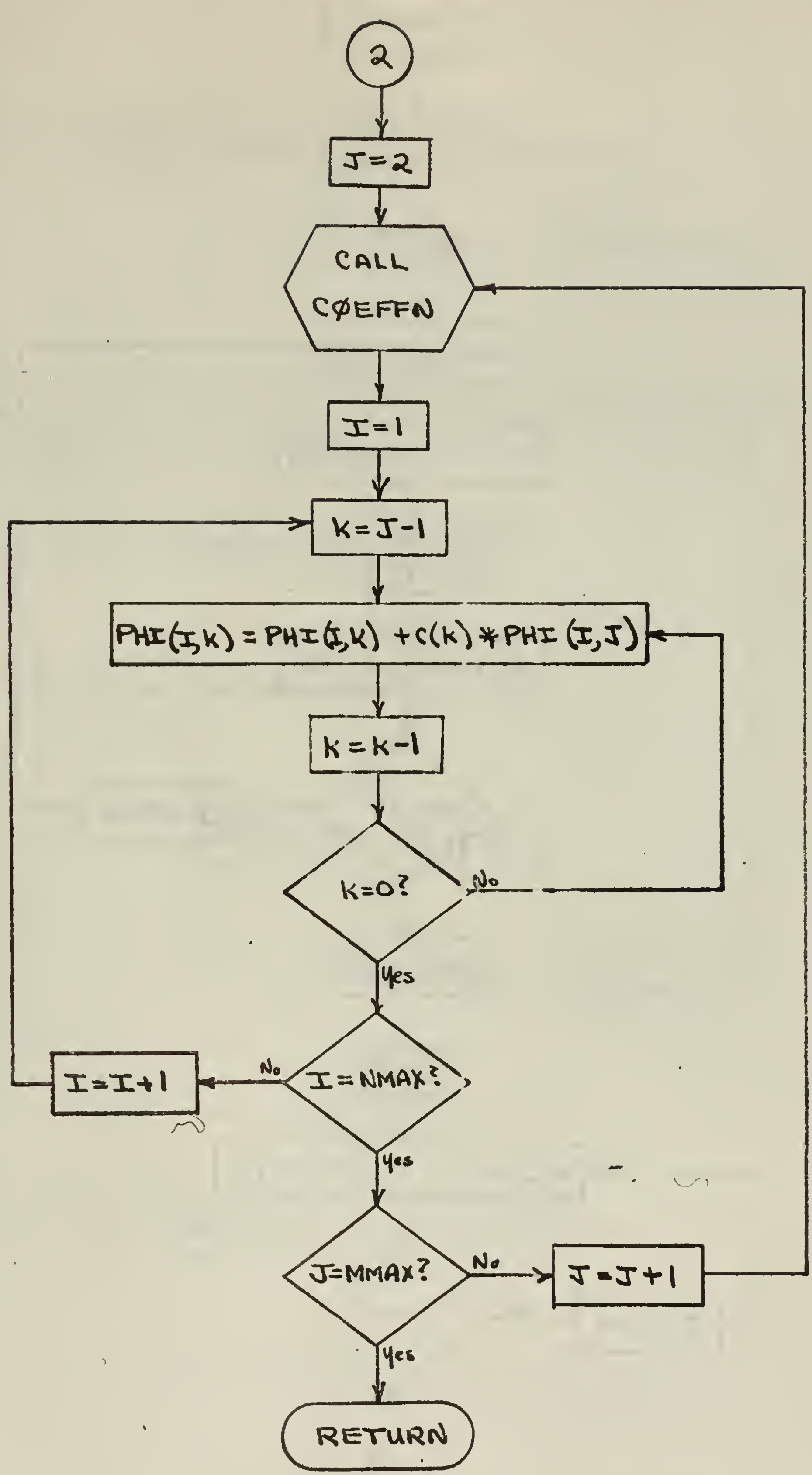

1
PHI(1,1) = PHI(1,1) + ZMEANZ
PRINT CØEFFICIENTS ØF APPRØXIMATING PØLYNØMIAL
PRINT
MEAN SQUARED
CØMPUTED MEAN SQUARED
MAXIMUM DIFFERENCES
RETURN

SUBRØUTINE PØLYXY



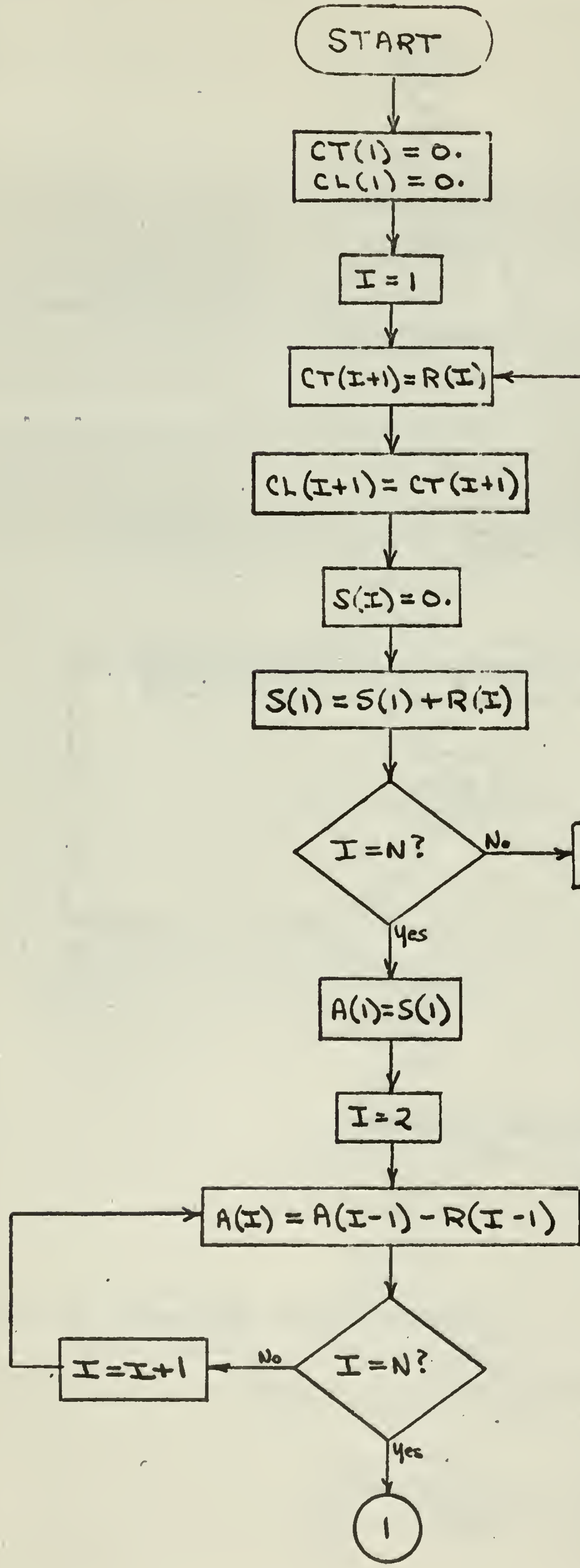

S/R
PØLYXY
1
I = 2
CALL
CØEFFN
J=1
K=I-1
PHI(K,J)=PHI(K,J) + C(K)*PHI(I,J)
K=K-1
K=0?
No
yes
J=JMAX?
No
J=J+1
yes
I=NMAX?
No
I=I+1
yes
I=1
R(I) = -YMEANY
I=MM1?
No
I=I+1
yes
2

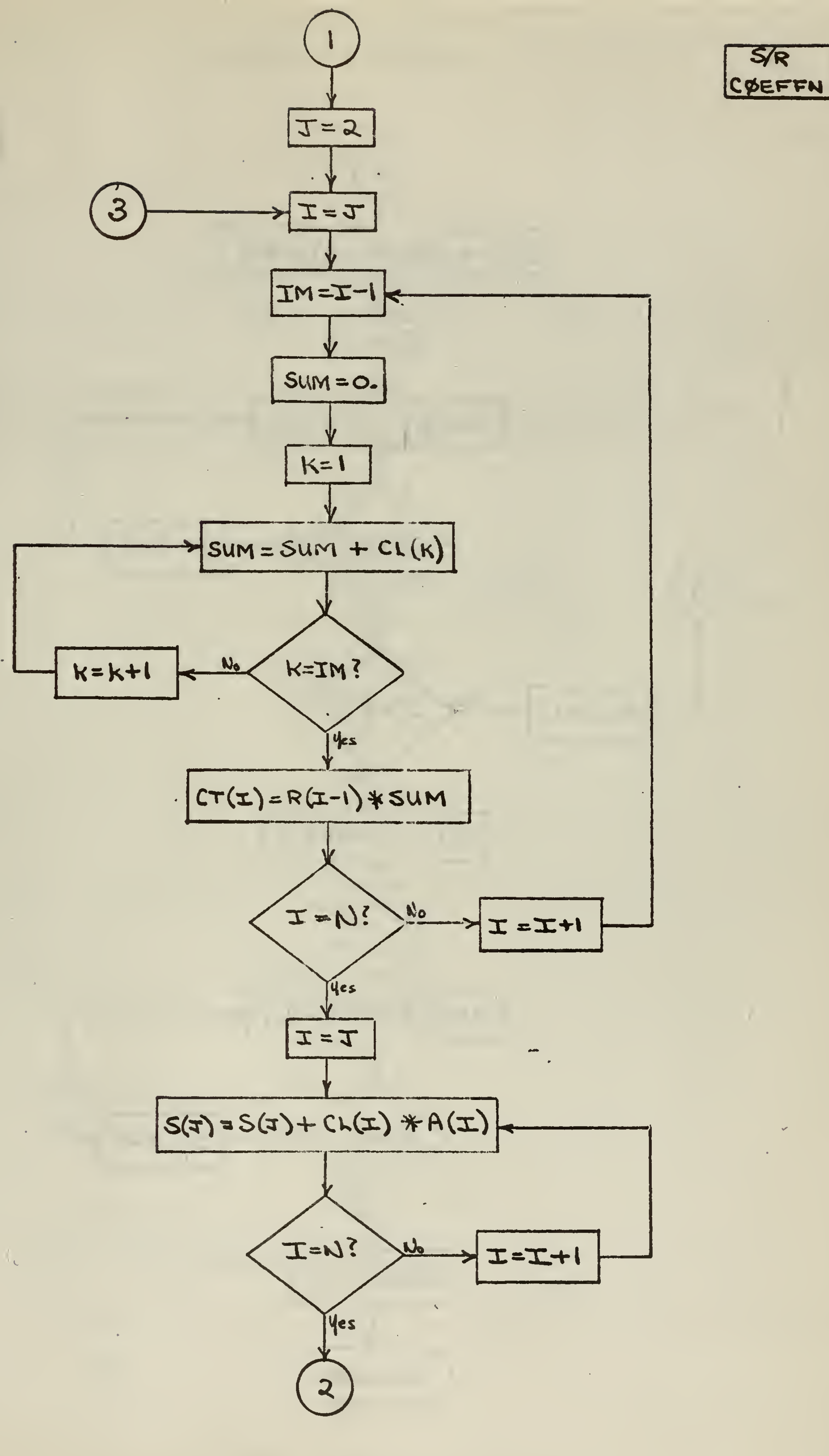
S/R
PØLYXY

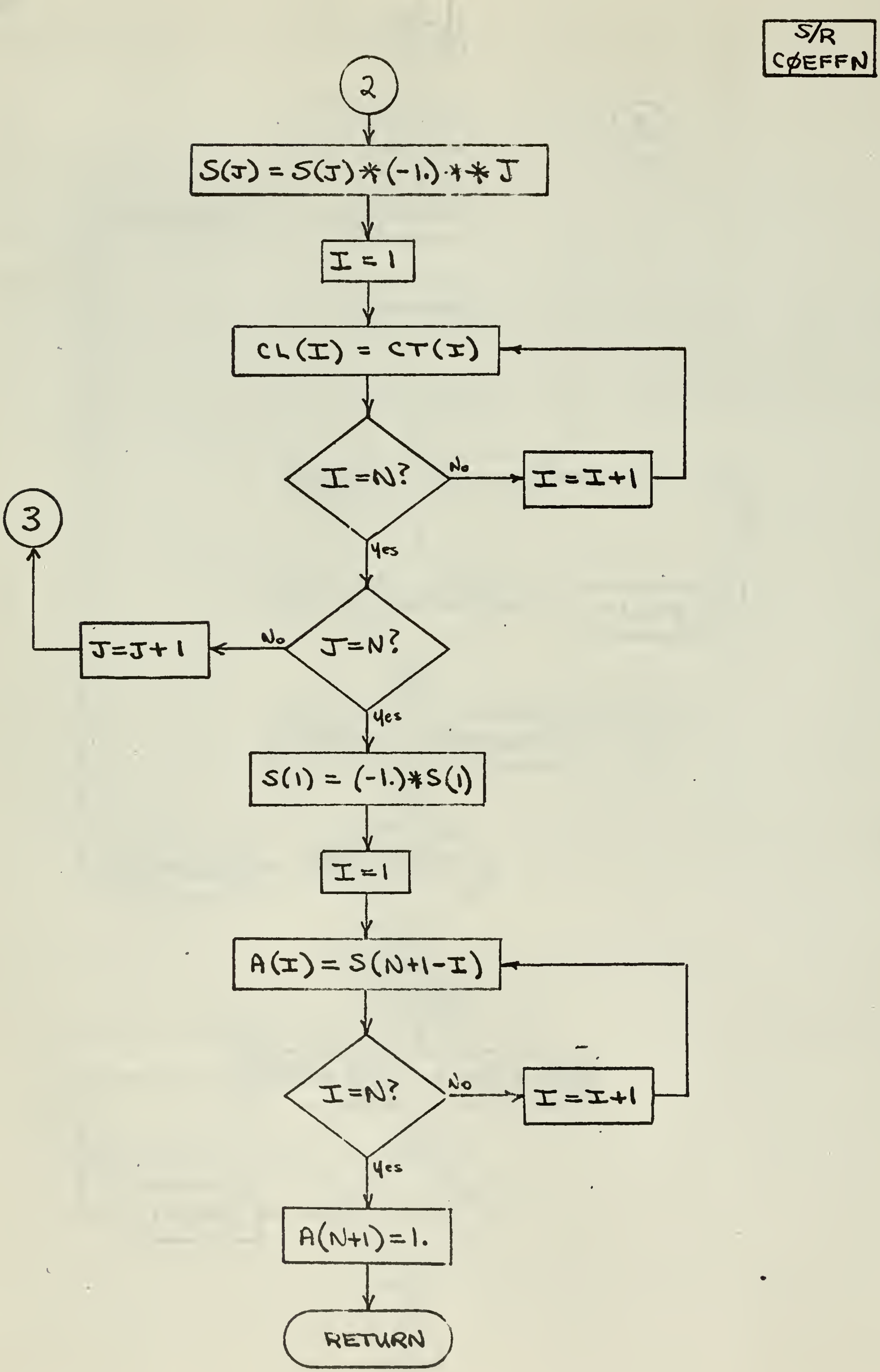


2
J=2
CALL
CØEFFN
I=1
K=J-1
PHI(I,K) = PHI(I,K) + C(K) * PHI (I,J)
K=K-1
K=0?
No
Yes
I=I+1
No
I=NMAX?
Yes
J=MMAX?
No
J=J+1
Yes
RETURN

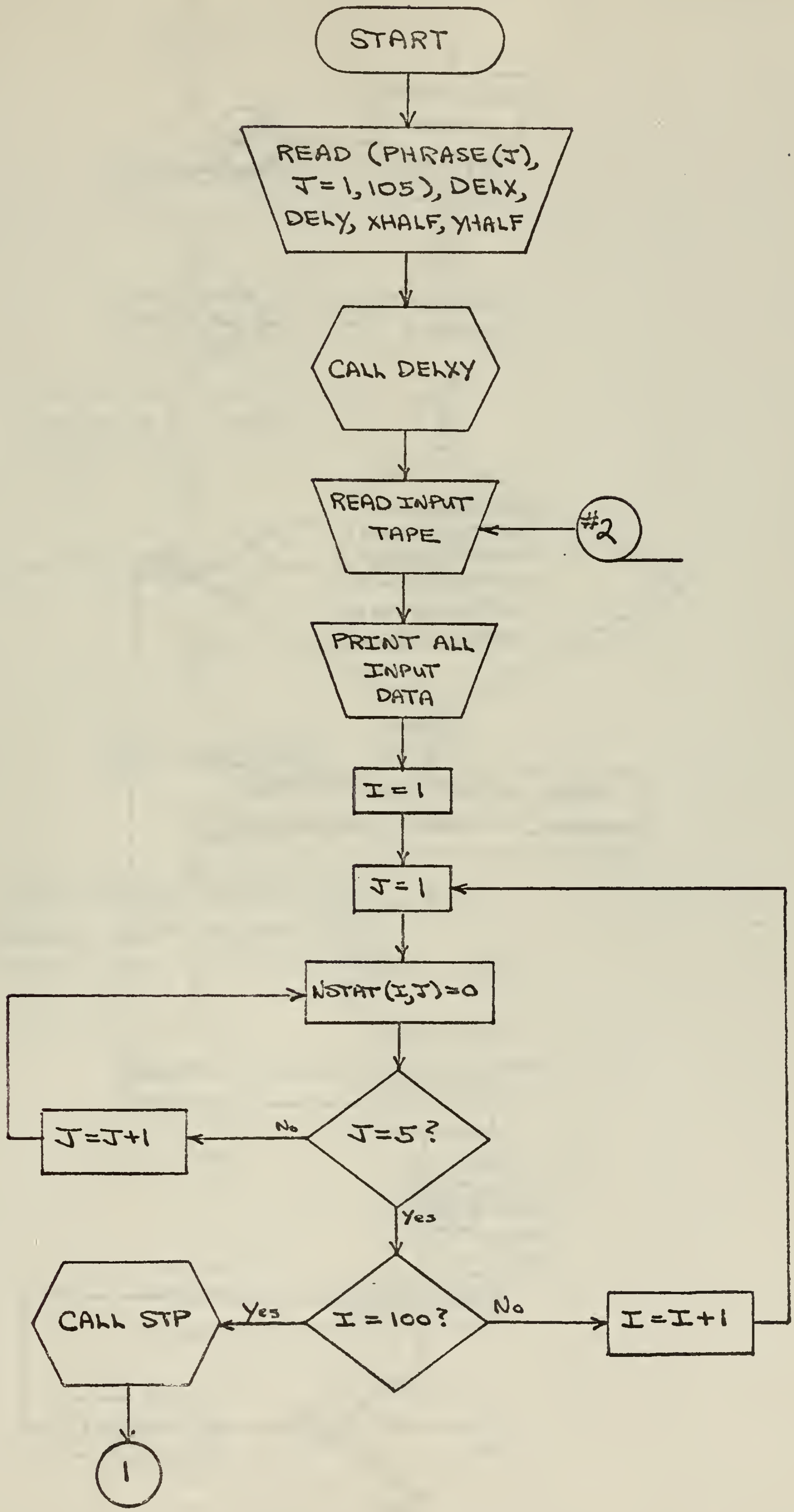
SUBROUTINE COEFFN



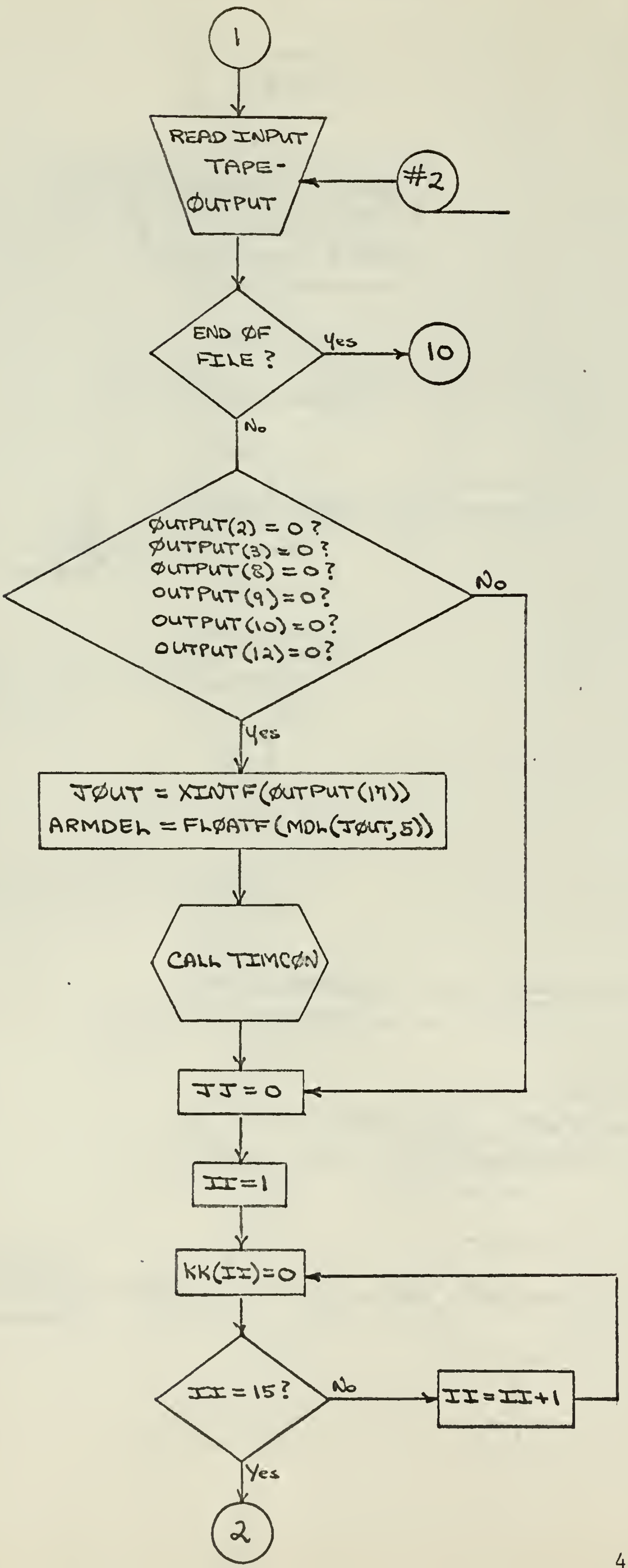

S/R
CØEFFN
1
J=2
3
I=J
IM=I-1
SUM=0.
K=1
SUM=SUM + CL(K)
K=IM?
No
K=K+1
Yes
CT(I)=R(I-1)*SUM
I=N?
No
I=I+1
Yes
I=J
S(J)=S(J)+CL(I)*A(I)
I=N?
No
I=I+1
Yes
2

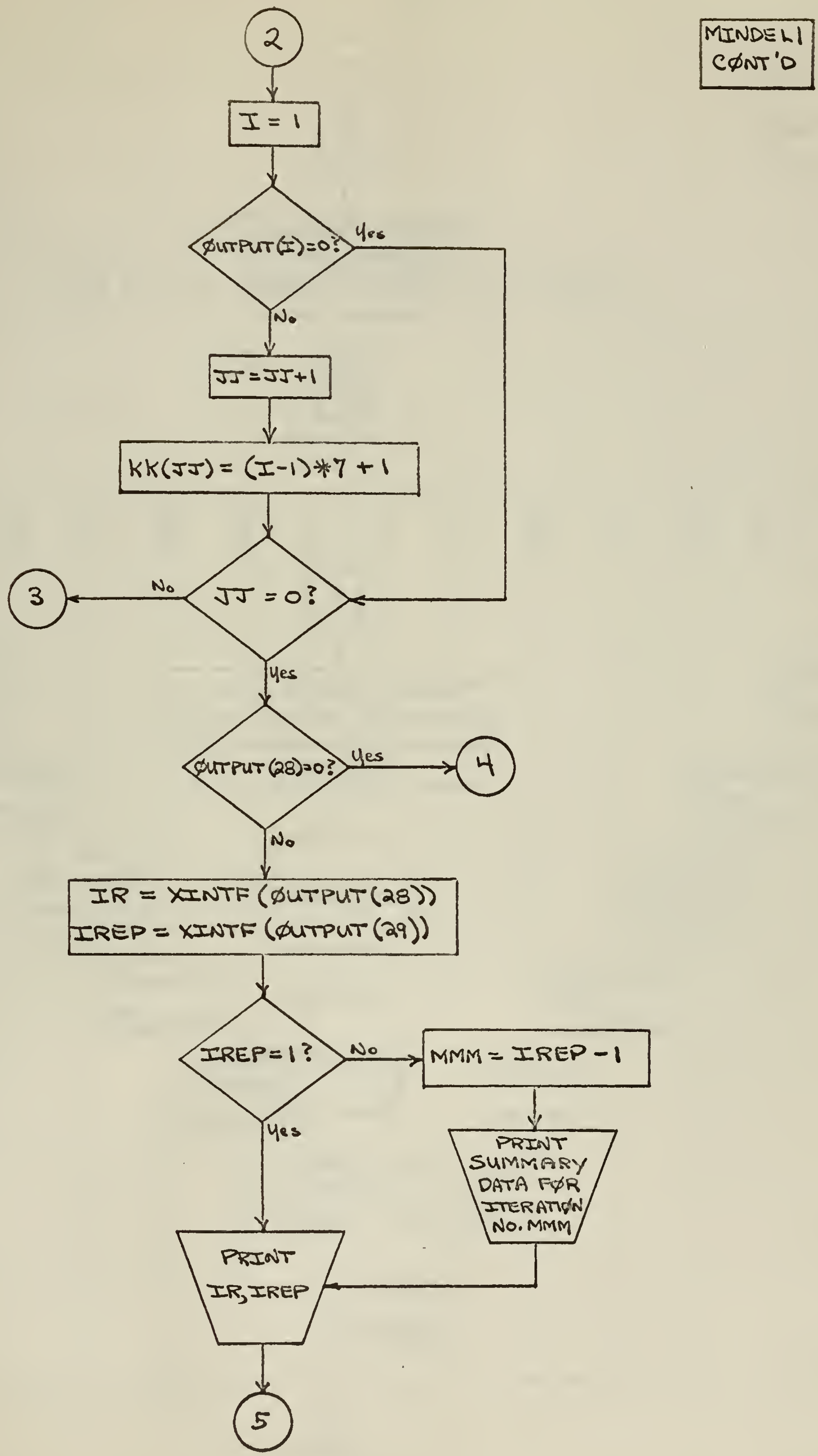

S/R
CØEFFN
2
S(J) = S(J)*(-1.)**J
I = 1
CL(I) = CT(I)
I = N?
No
I = I+1
Yes
3
J=J+1
No
J=N?
Yes
S(1) = (-1.)*S(1)
I = 1
A(I) = S(N+1-I)
I = N?
No
I = I+1
Yes
A(N+1) = 1.
RETURN

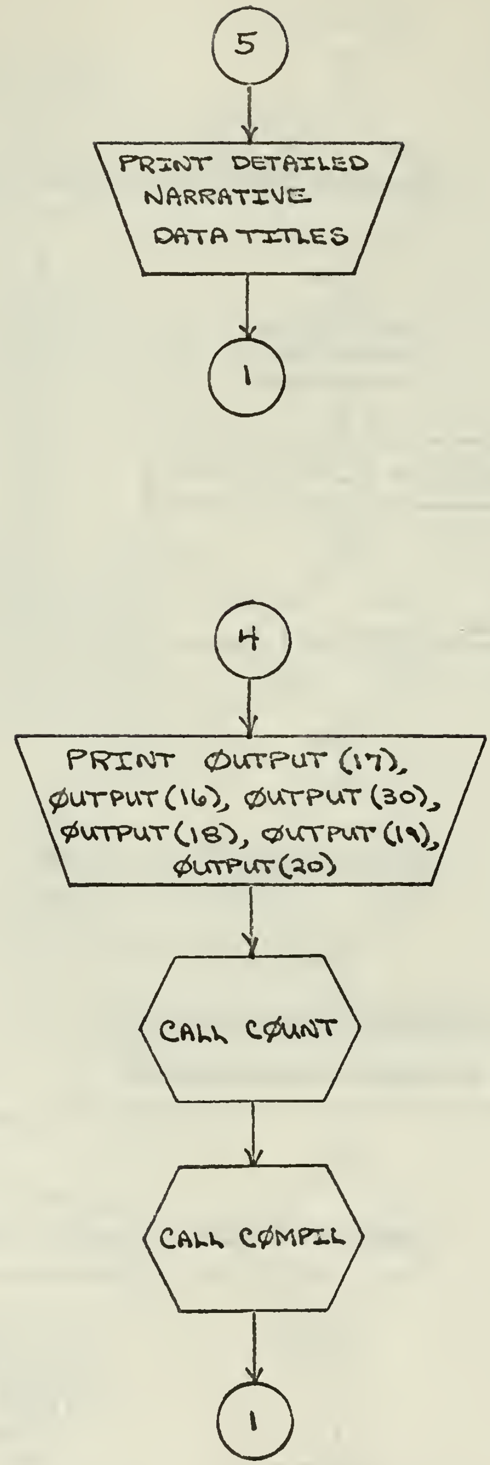
PRØGRAM MINDEL1

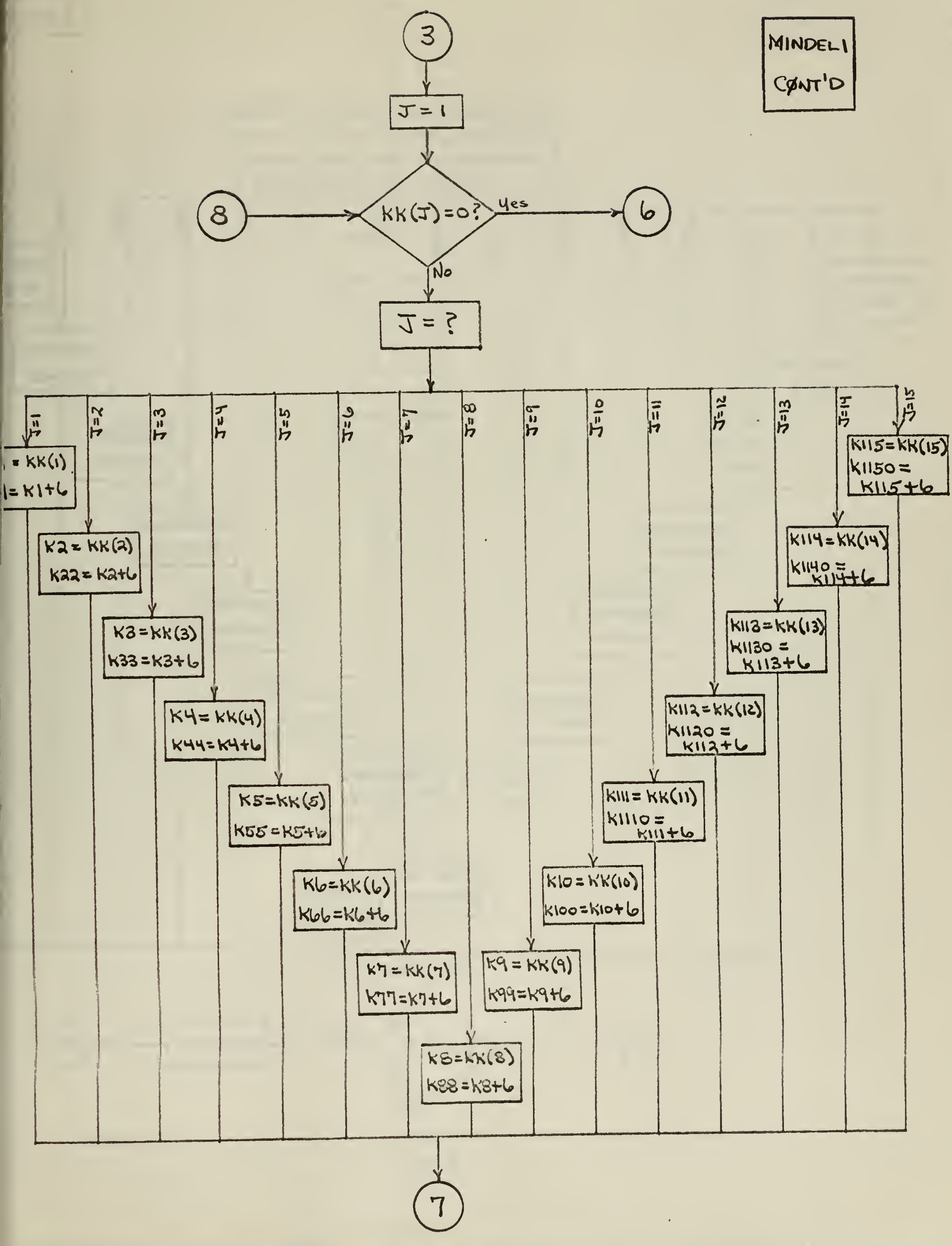


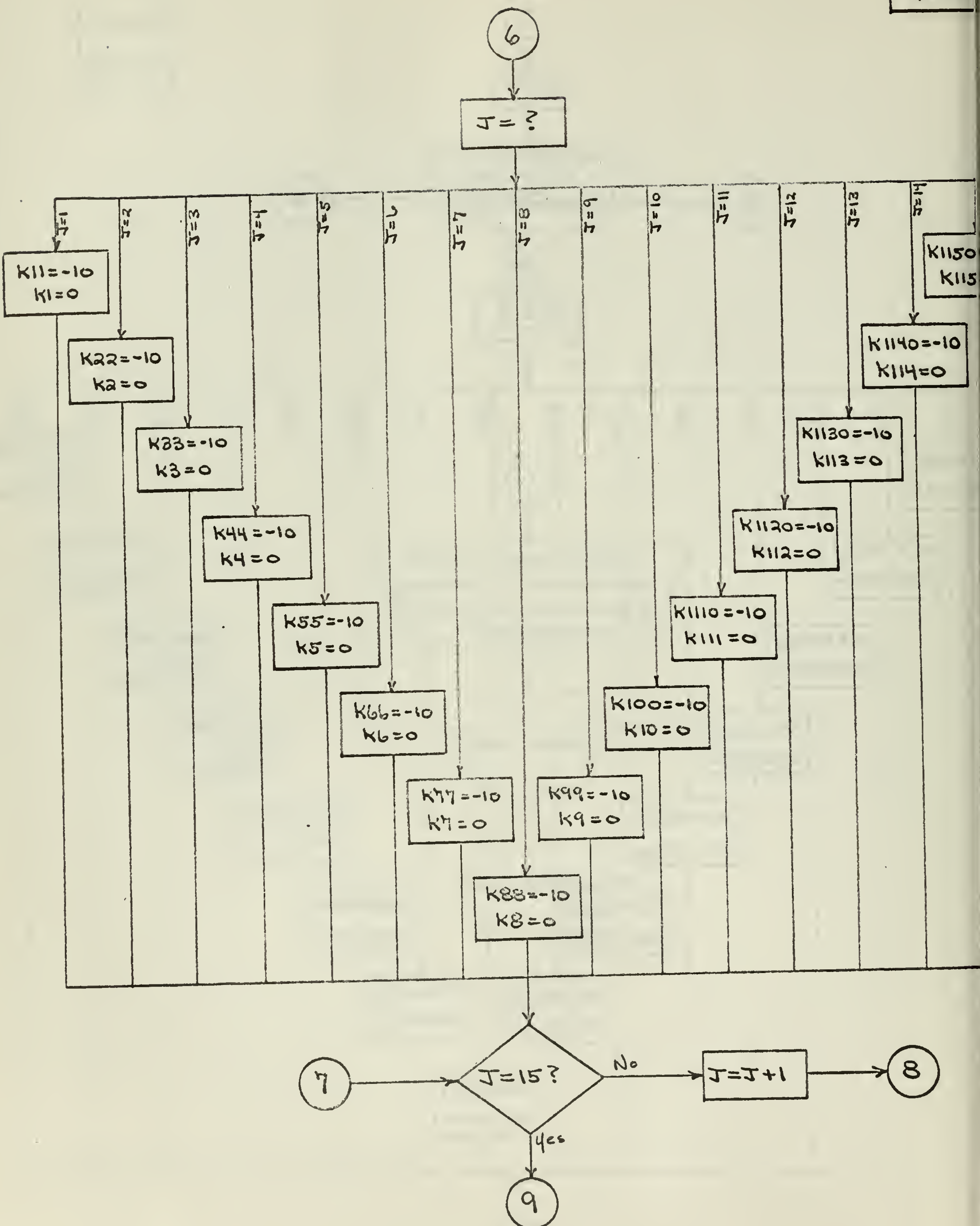
MINDEL1 CØNT'D



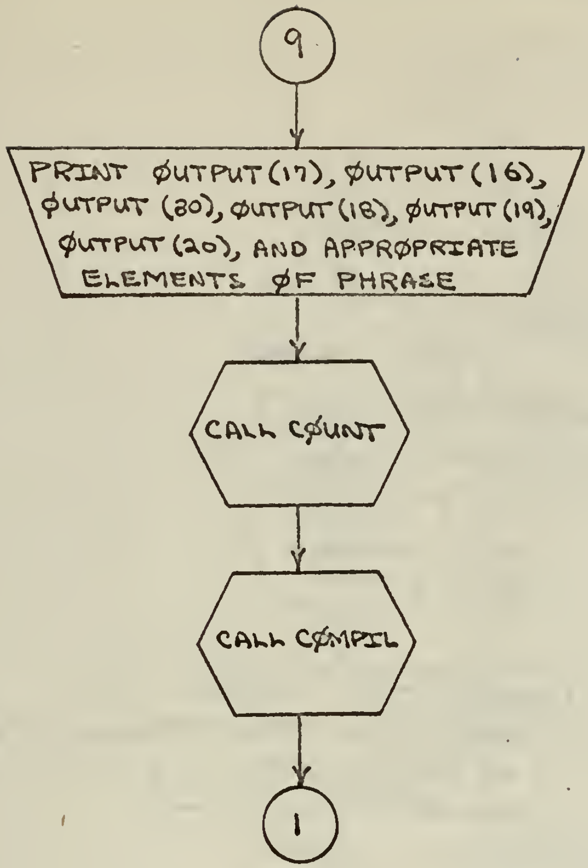

MINDEL1
CØNT'D
2
I = 1
ØUTPUT(I)=0?
Yes
No
JJ = JJ+1
KK(JJ) = (I-1)*7 + 1
JJ = 0?
No
3
Yes
ØUTPUT(28)=0?
Yes
4
No
IR = XINTF (ØUTPUT(28))
IREP = XINTF (ØUTPUT(29))
IREP=1?
No
MMM = IREP - 1
PRINT SUMMARY DATA FØR ITERATIØN NO. MMM
Yes
PRINT IR, IREP
5

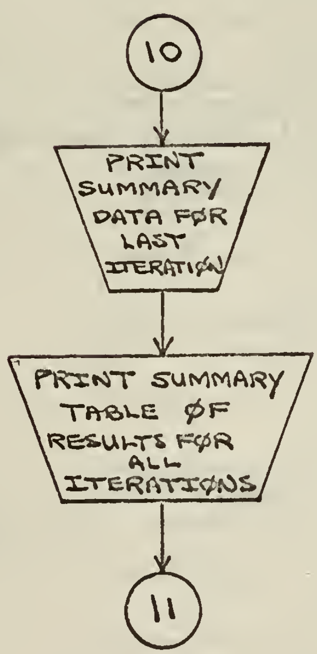

5
PRINT DETAILED NARRATIVE DATA TITLES
1
4
PRINT ØUTPUT (17), ØUTPUT (16), ØUTPUT (30), ØUTPUT (18), ØUTPUT (19), ØUTPUT (20)
CALL CØUNT
CALL CØMPIL
1

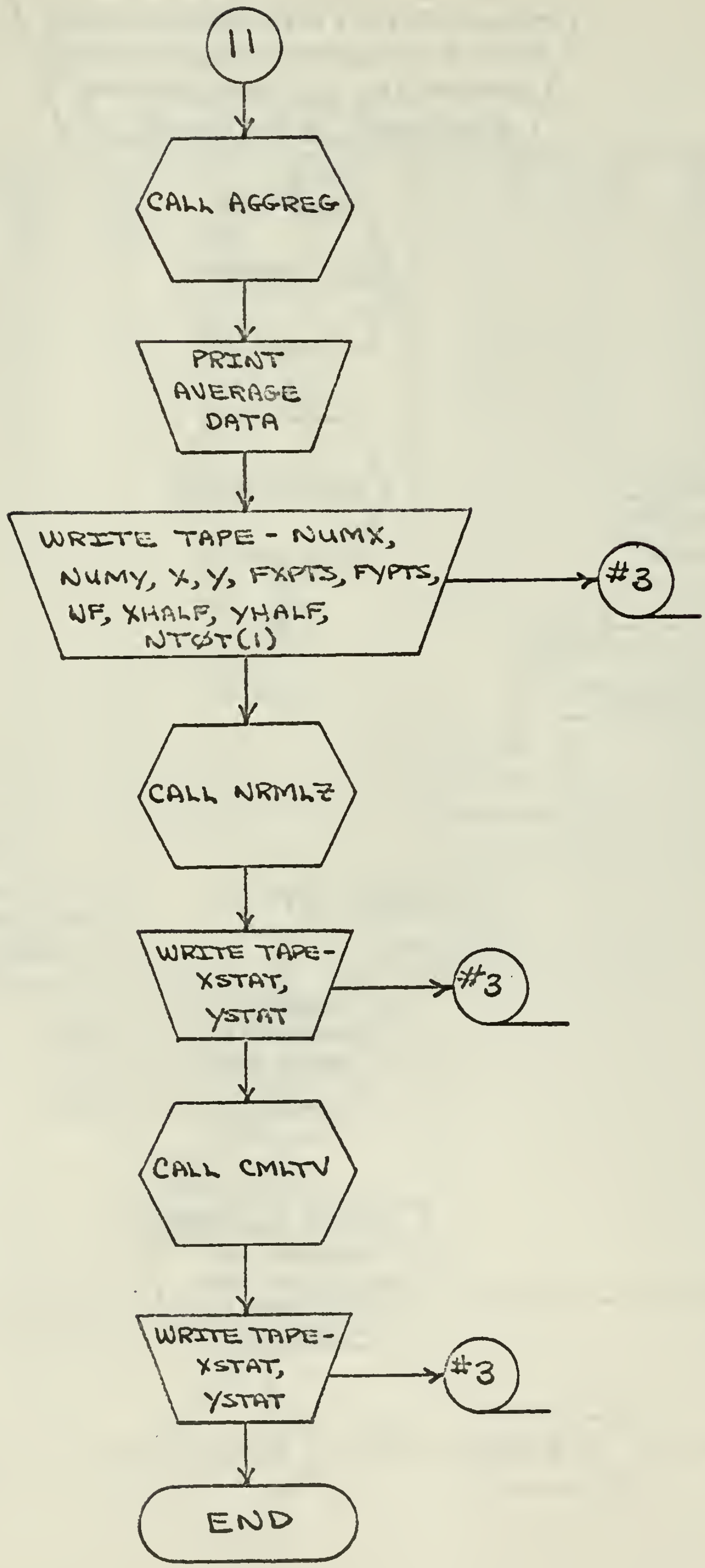

MINDEL1
CØNT'D
3
J = 1
8
KK(J) = 0?
Yes
6
No
J = ?
J=1
J=2
J=3
J=4
J=5
J=6
J=7
J=8
J=9
J=10
J=11
J=12
J=13
J=14
J=15
= KK(1)
= K1+6
K2 = KK(2)
K22 = K2+6
K3 = KK(3)
K33 = K3+6
K4 = KK(4)
K44 = K4+6
K5 = KK(5)
K55 = K5+6
K6 = KK(6)
K66 = K6+6
K7 = KK(7)
K77 = K7+6
K8 = KK(8)
K88 = K8+6
K9 = KK(9)
K99 = K9+6
K10 = KK(10)
K100 = K10+6
K111 = KK(11)
K1110 = K111+6
K112 = KK(12)
K1120 = K112+6
K113 = KK(13)
K1130 = K113+6
K114 = KK(14)
K1140 = K114+6
K115 = KK(15)
K1150 = K115+6
7


6
J = ?
J=1
J=2
J=3
J=4
J=5
J=6
J=7
J=8
J=9
J=10
J=11
J=12
J=13
J=14
K11=-10
K1=0
K22=-10
K2=0
K33=-10
K3=0
K44=-10
K4=0
K55=-10
K5=0
K66=-10
K6=0
K77=-10
K7=0
K88=-10
K8=0
K99=-10
K9=0
K100=-10
K10=0
K1110=-10
K111=0
K1120=-10
K112=0
K1130=-10
K113=0
K1140=-10
K114=0
K1150
K115
7
J=15?
No
J=J+1
8
Yes
9

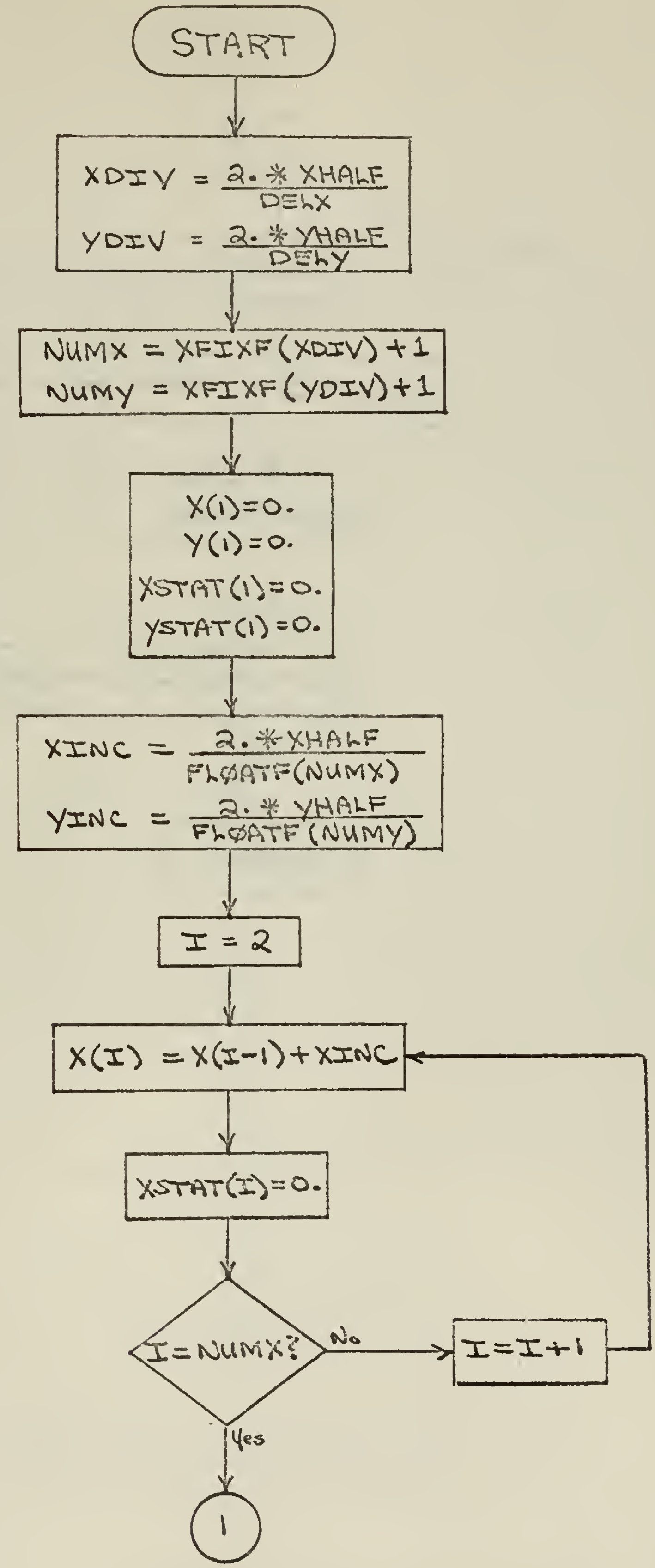
MINDELI CØNT'D



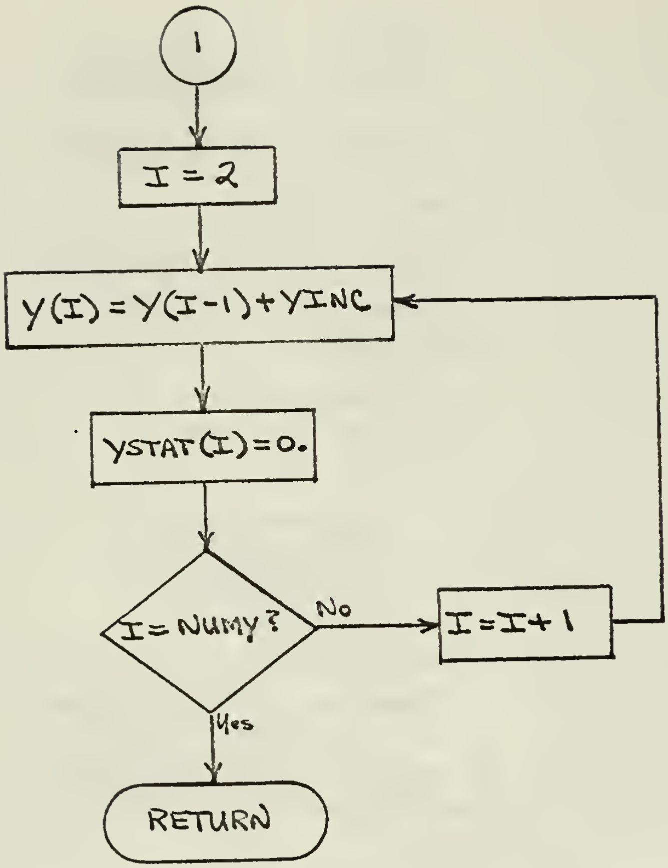



11
CALL AGGREG
PRINT AVERAGE DATA
WRITE TAPE - NUMX, NUMY, X, Y, FXPTS, FYPTS, WF, XHALF, YHALF, NTØT(1)
#3
CALL NRMLZ
WRITE TAPE - XSTAT, YSTAT
#3
CALL CMLTV
WRITE TAPE - XSTAT, YSTAT
#3
END

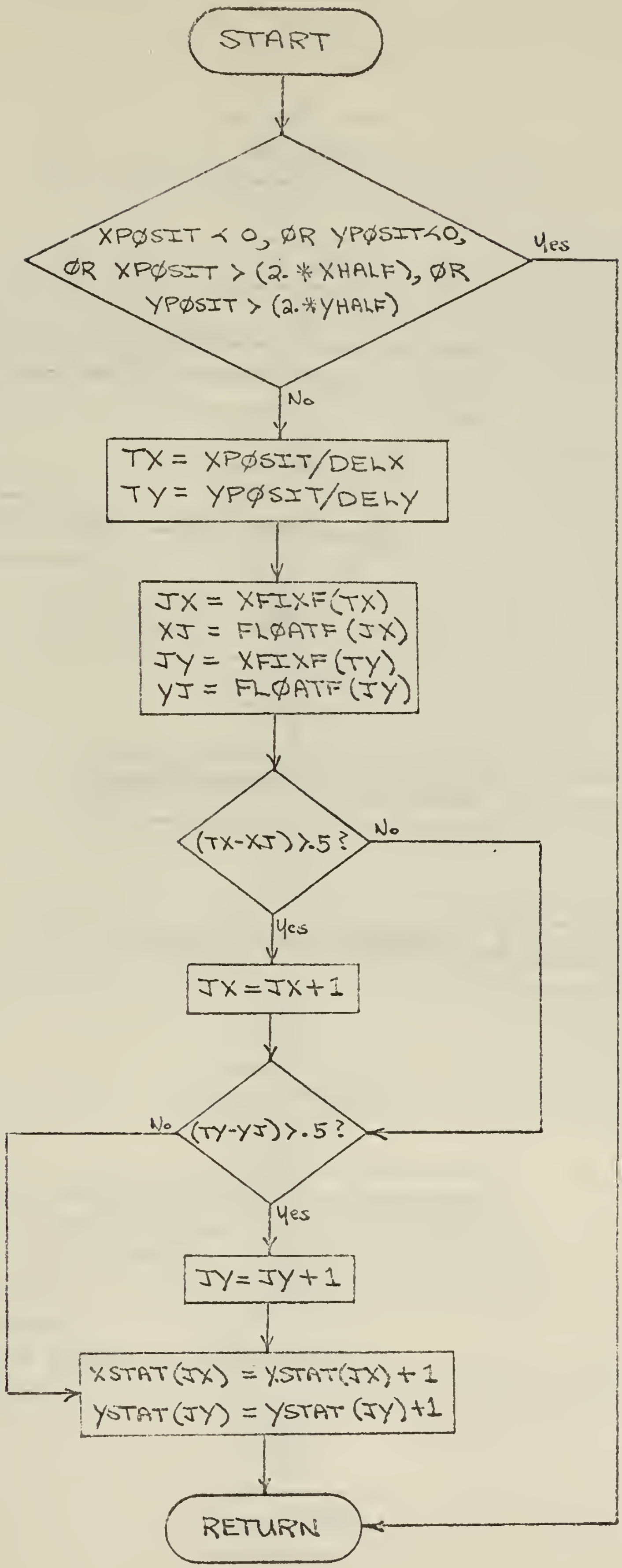
SUBRØUTINE DELXY



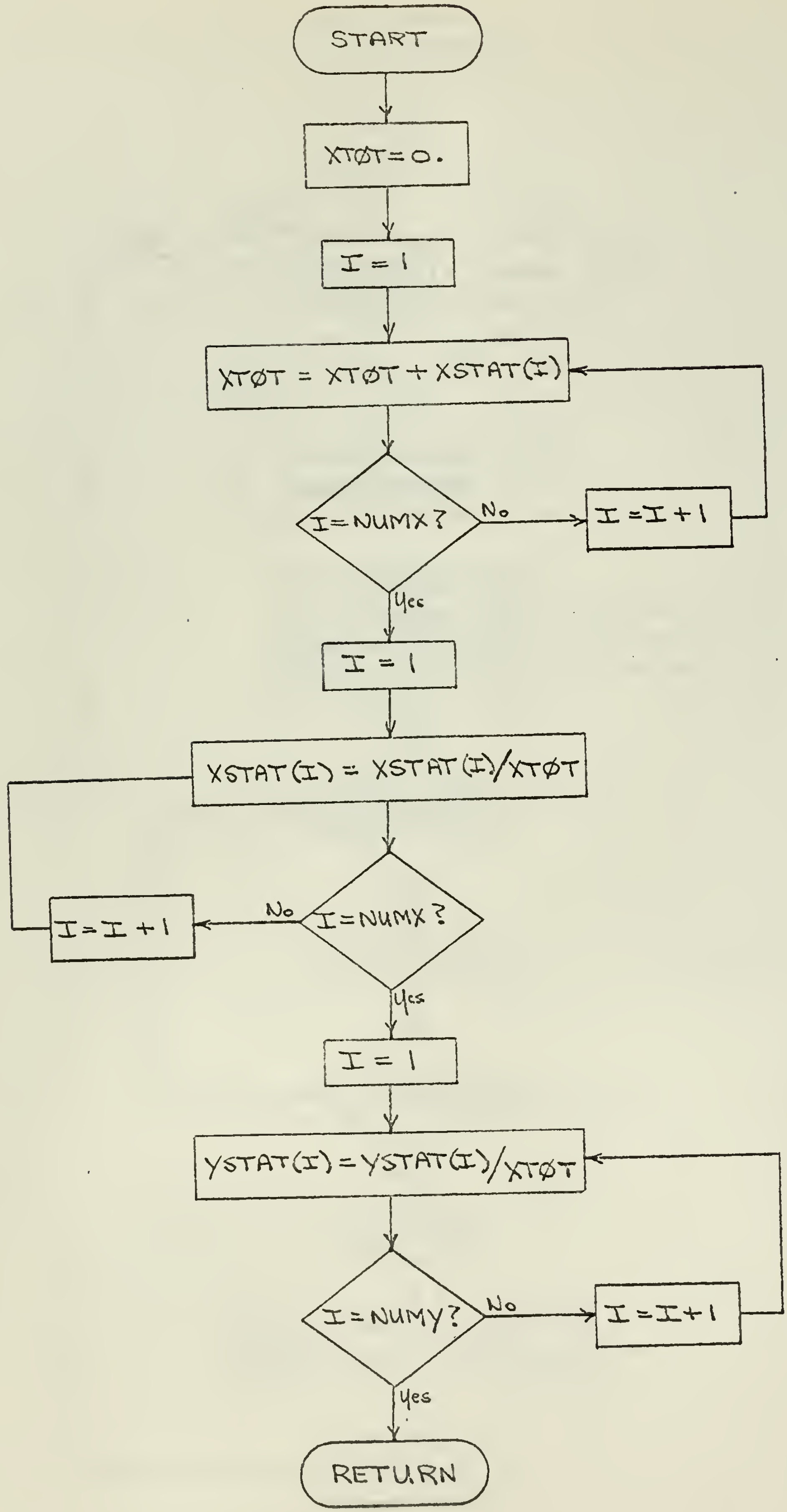
S/R
DELXY
CONT'D



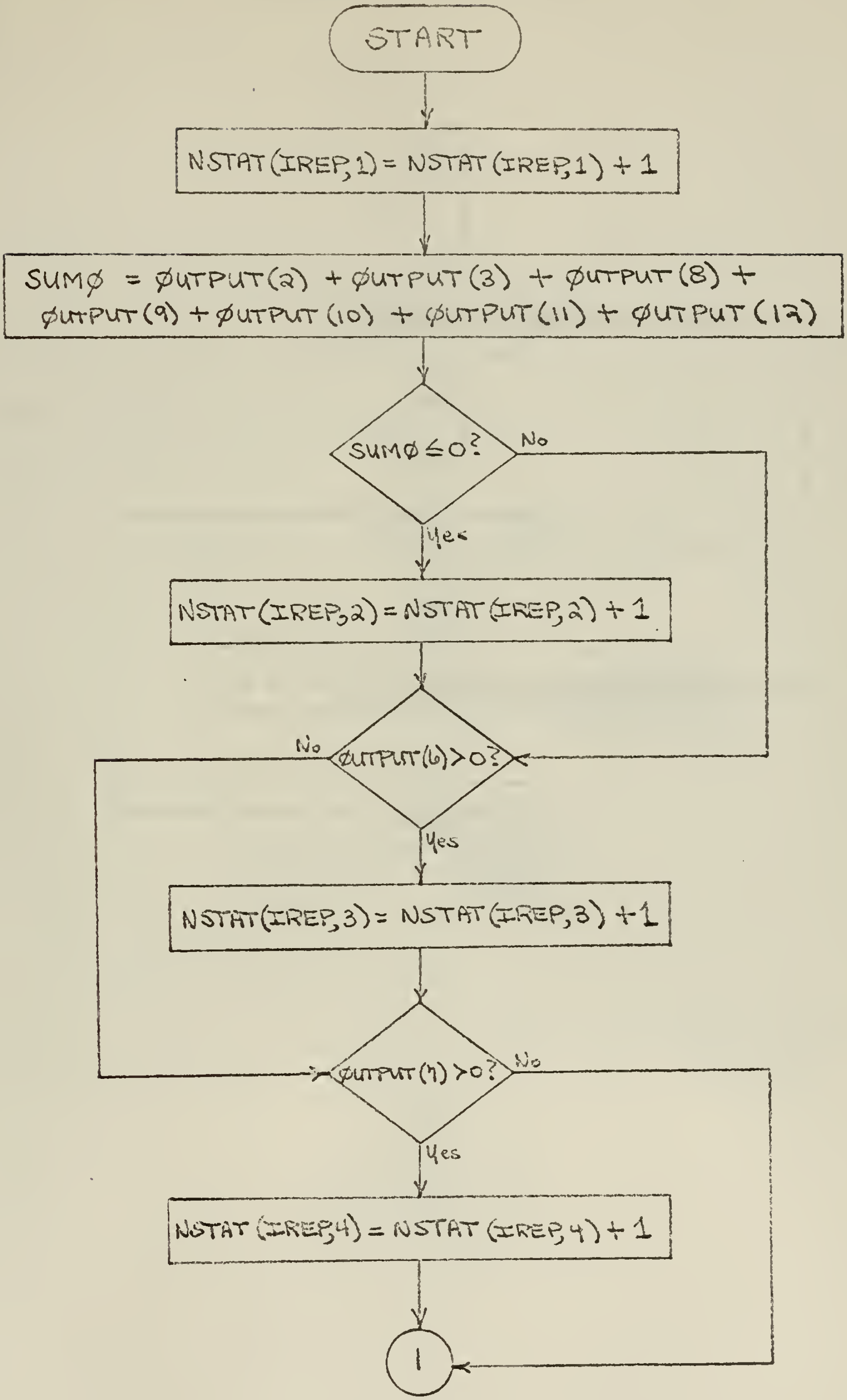
SUBRØUTINE CØUNT



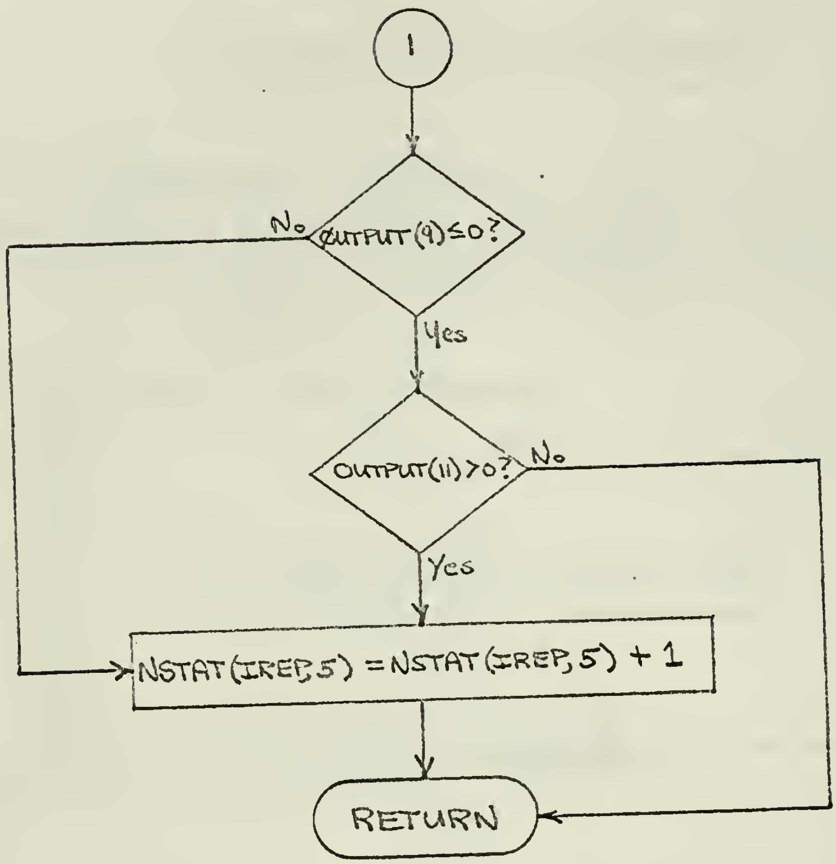
SUBRØUTINE NRMLZ



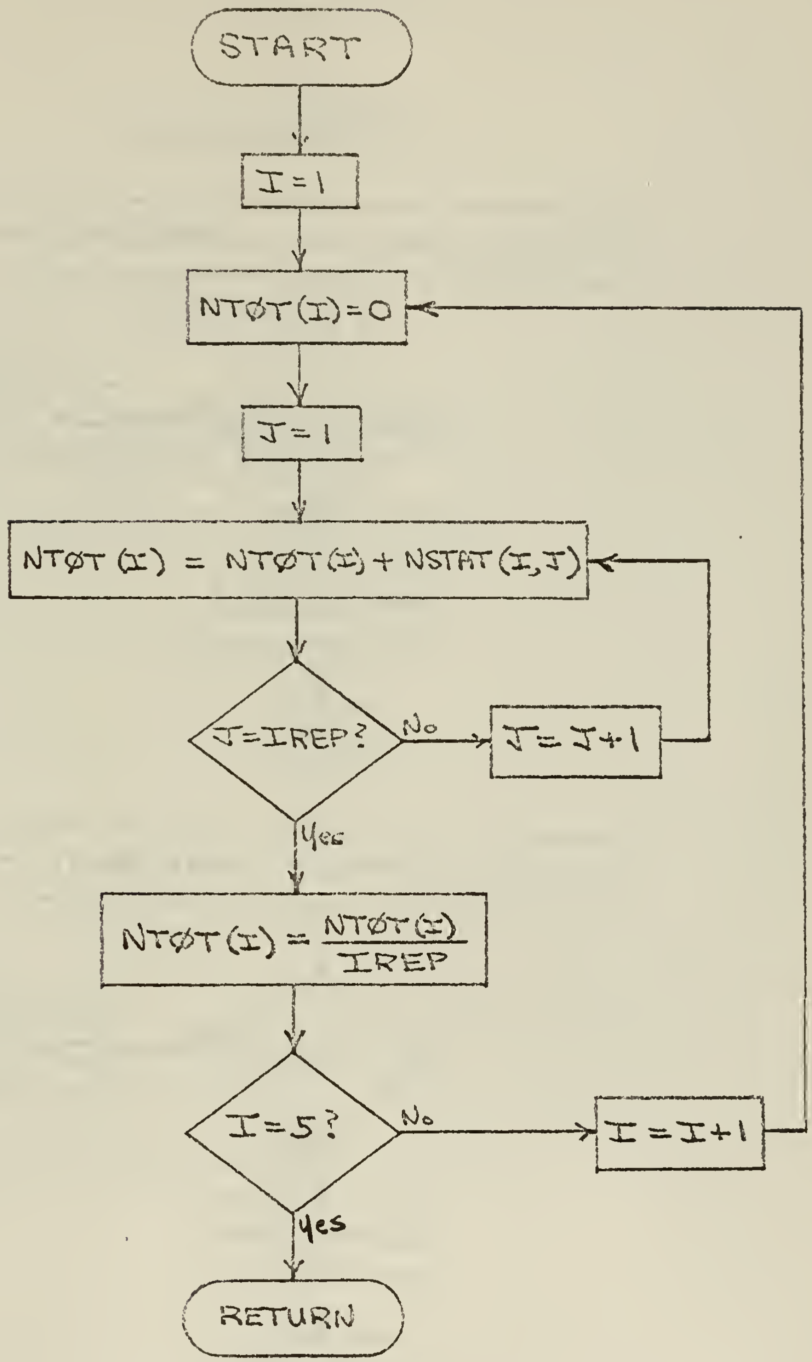
SUBRØUTINE CØMPIL



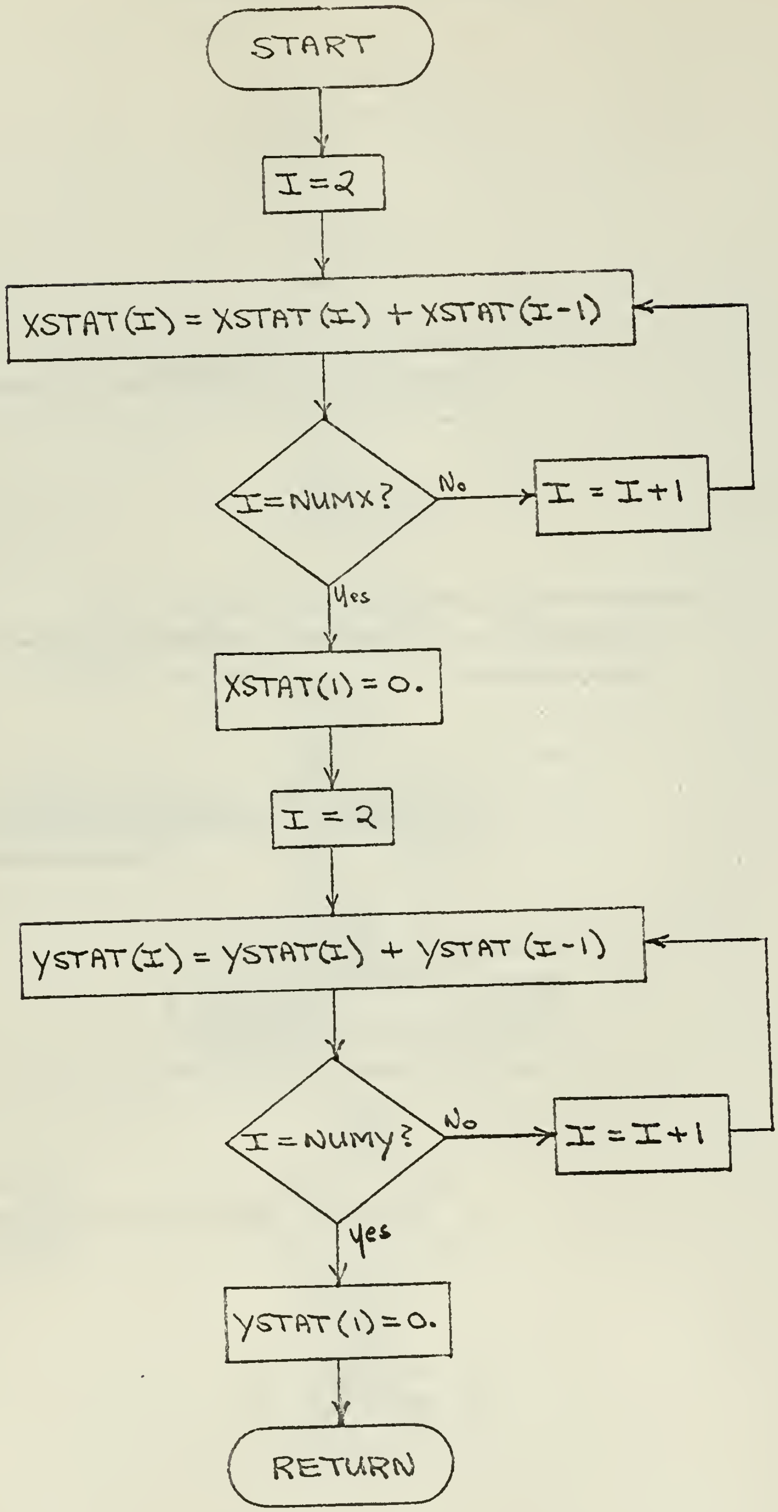
S/R
CØMPIL
CØNT'D



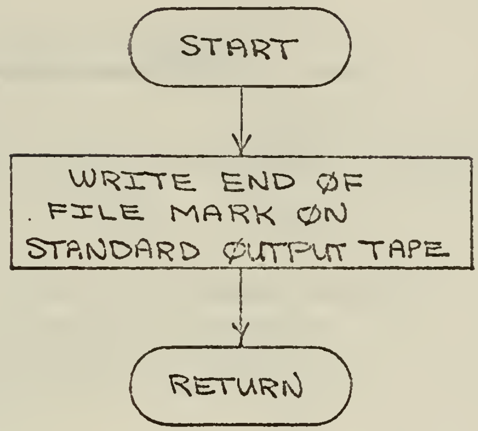
SUBRØUTINE AGGREG



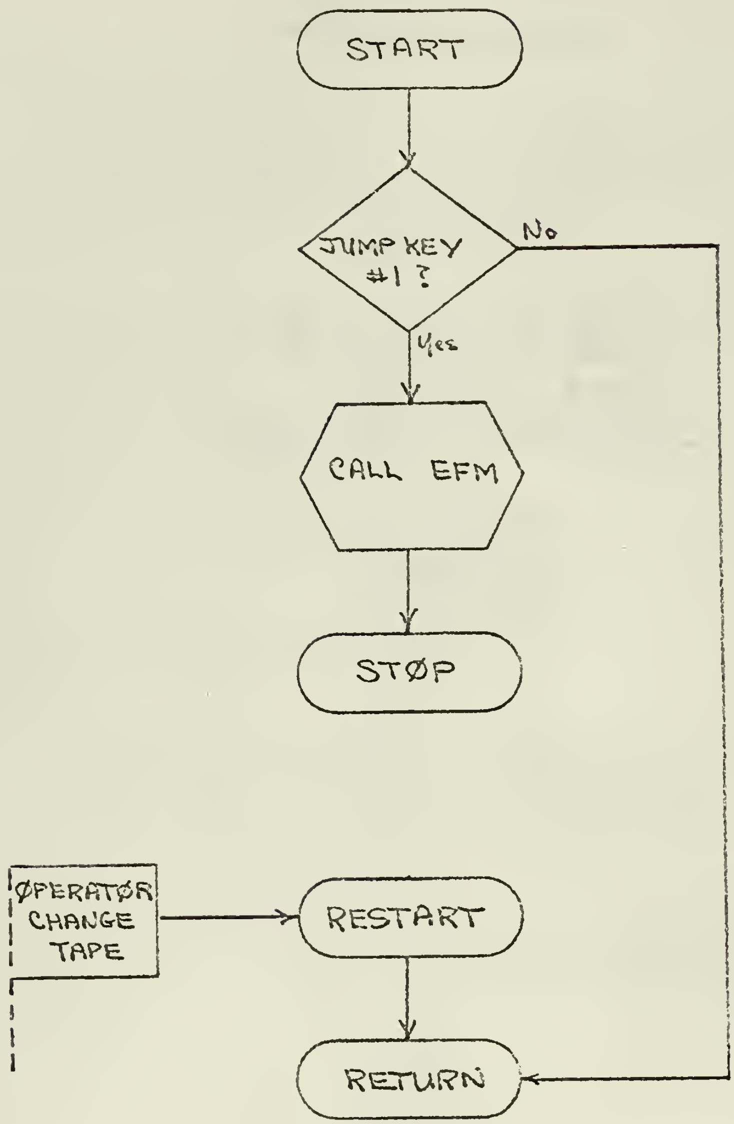
SUBRØUTINE CMLTV



SUBRØUTINE EFM



Subroutine STP



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13. ABSTRACT

The Mine Delivery Model is a Monte Carlo computer simulation of the delivery of mines in detail by ships, submarines, and/or aircraft. Inputs are of such a nature as to permit the simulated execution of any specific mining plan and the outputs provide sufficient information for subsequent evaluation of the plan by a threat assessment model.

The model as programmed for the CDC 1604 Computer consists of five programs. The first two programs convert input data, the third and main program is the mine delivery simulation, the fourth program provides a detailed printout of both inputs and game results, i.e., the calculated parameters for each mine layed accompanied by selected statistics, and the fifth program provides statistics and graphs on the distributions of the mine positions.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Mine Delivery						
Mine Warfare						
War Gaming, Digital Computer						
Simulation, Digital Computer						

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